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ARS-73-69
(EU. PUBL. No. 3340)

Proceedings...

WHEY
Utilization Conference

June 2 and 3, 1970

University of Maryland
College Park, Maryland

Agricultural Research Service
UNITED STATES DEPARTMENT of AGRICULTURE

WHEY UTILIZATION CONFERENCE

University of Maryland
College Park, Maryland

This first Whey Utilization Conference was designed as a forum for the exchange of information among industry, university, and government workers engaged in the research, development, and manufacture of whey products and among cheese producers with disposal problems. The excellent attendance at the conference reflected current emphasis on reducing the Nation's environmental pollution, and specifically on the need for developing constructive and profitable uses for whey rather than directing it to expensive waste-disposal facilities. The conferees noted that complete recovery of whey in the United States would more than double the current supply of whey solids, thus necessitating a vigorous program of new products research and development.

The second Whey Utilization Conference is planned for the fall of 1971, and will be cosponsored by the Eastern Utilization Research and Development Division of USDA's Agricultural Research Service and the University of Wisconsin. The conference will be held at the University of Wisconsin. For information on it, contact the Department of Food Science and Industries, University of Wisconsin, Madison, Wis. 53706; or the Dairy Products Laboratory, Eastern Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture, Washington, D. C. 20250.

Additional copies of these proceedings are available from:

Eastern Utilization Research and Development Division
Agricultural Research Service
U. S. Department of Agriculture
600 East Mermaid Lane
Philadelphia, Pennsylvania 19118

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October 1970

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Theme: Pollution or Utilization

OPENING REMARKS BY THE CHAIRMAN

F. R. Senti
Deputy Administrator for Marketing and Nutrition Research
Agricultural Research Service, USDA
Washington, D. C.

On behalf of the Agricultural Research Service and our Eastern Utilization Research and Development Division, I am pleased to welcome you to this conference on whey utilization.

The Eastern utilization division is one of five research divisions of the Agricultural Research Service which have as a major mission the better utilization of agricultural commodities. They are concerned with developing new and improved products and with increasing the efficiency of processes for making existing products. Although some attention has been given to byproducts and processing wastes in this work, until recently research effort has been largely concentrated on the primary products.

Heretofore, economic considerations generally have not favored utilization of wastes as raw materials for product development. This situation has changed. With the increasing concern about environmental quality, traditional methods of waste disposal can no longer be practiced, and permissible disposal methods will entail considerably more expense. Under this new situation the possibilities for waste utilization require re-examination. There is now a credit to be gained by avoiding the costs of waste disposal. Indeed, the entire processing technology for agricultural commodities requires re-examination. With low-cost methods for disposal of plant wastes no longer available, processes need to be devised which minimize waste formation; moreover, those wastes which are produced should be collected in concentrated form, if possible, in order to facilitate their subsequent utilization or disposal and to avoid the need for recovery from dilute solutions.

Research on such processing methods is underway in each of our utilization laboratories in areas dealing with fruits and vegetables, vegetable oil refining, textile processing, and poultry processing. In this research we cooperate with industry, with the Federal Water Quality Administration, and with the State agricultural experiment stations.

In this morning's session we shall develop a background for more detailed discussion of processing methods and product utilization from whey.

But before we begin our program, I want to introduce you to Dr. Richard F. Davis, Head, Department of Dairy Science, University of Maryland, who represents the University as co-sponsor of this conference.

WELCOME

Richard F. Davis
Head, Department of Dairy Science
University of Maryland
College Park, Md.

It is a real privilege for me to be able to participate in this conference and represent the University of Maryland and its Department of Dairy Science in saying a few words of greeting to you. One of my pleasant tasks this morning is to participate in a program which represents the degree of cooperation we see here between the university, the U. S. Department of Agriculture, and you people in industry. I think this is an excellent example of the kind of cooperation it is going to take to solve many of the very serious problems that are going to be facing us in the immediate future and for several years to come.

We are here because, at least to some extent, there are a number of social pressures that face us all. Society is telling us we can't dump the disposal from milk processing plants in the streams or in other locations because it is going to pollute them. Dr. Senti has reviewed the picture with respect to whey disposal.

I think we can see a number of challenges in the total dairy industry. Looking at the situation in a little broader sense, Dr. Jean Mayer, the President's consultant on nutrition, was on our campus about three weeks ago. During his public presentations, he declared that man in his development of technology has now reached the point where he can provide the necessities of life--food, clothing, shelter--and he has reached the point where he can philosophize a bit and decide upon the kind and the quality of the life he wants to live and the kind of environment in which he wants to live that life. It seems to me--and I think it does to you because you're here--that we are going to have to respond in a rather positive way to those demands of society.

Specifically, we are here today to seek ways to utilize whey, an important byproduct of our industry. But in addition to this, I see a number of challenges ahead of us as an industry in terms of developing products that are free of contamination, of things that bother people. We will have to have information on the contaminants in our food. We are going to have to know about the things that are in dairy products other than the things that the cow puts into them. We are going to have to understand these things and have answers to the questions people ask about the quality of our product.

We're also going to have to understand the capability of this product to fit in with our total food pattern. We need to develop some additional food products from other constituents of milk besides whey, and we need to be aware of the opportunities as well as the problems.

We also need to consider changing some restrictive legislation. If milk is to retain its strong competitive position as a basic commodity in our total food situation, we need to change our thinking about the opportunities for getting it used as an ingredient in other mixed and pre-prepared foods.

In the next two days you are going to be devoting your 150 to 175 minds to some pretty serious thinking on the subject of whey disposal and whey utilization. I am hoping that when you return to your individual locations you will take with you something from this conference that will work towards a solution of this problem on a National basis.

USDA PROGRAM FOR UTILIZATION

N. D. Bayley
Director, Science and Education
U. S. Department of Agriculture
Washington, D. C.

I will confine my comments this morning primarily to some of the challenges and opportunities we see in regard to processing wastes, leaving to Dr. Byerly the task of putting before you our broad concepts and concerns regarding environmental quality.

Our country's population has now reached about 204 million. Most of these Americans take for granted the constant availability of high-quality and wholesome foods. This availability has been possible primarily because science and technology have given agriculture and industry the tools to make farming, processing, and marketing more efficient and more effective in terms of providing the products consumers want. But these technological advances, as we are all aware, have been achieved at a price, and part of that price has been the contamination of our air, water, and soil.

It's true that during the years that our country was developing industrially, as well as agriculturally, there were few who gave much thought to the problems that indiscriminate waste disposal might create. The air, the water, and the soil were plentiful. We had other concerns on our minds, so we used the air, the water, and the soil as cheap, convenient disposal tanks. We can see the evidence of our carelessness everywhere today--in our industrial wastes, in the fumes from our automobile exhaust, in our salty soils contaminated with irrigation, erosion, and sedimentation as well as with residues from chemical and plant nutrients, in our waters polluted with food-processing wastes and other discharges from an increasingly affluent society.

Why don't we change this situation? It no longer matters who is responsible for it. The whole society is involved. The issue today is, What can we do about it? Doing something about it is going to take the cooperation of everybody--government, universities, industry, and people as individuals.

Devising ways to reduce food-processing wastes is one area that lends itself readily to such cooperation. USDA research takes two general approaches to this job. First, we try to alter processing techniques so that fewer waste materials will be produced. Second, if this is not feasible, we look for ways to recover large amounts of waste material and define projected uses for them. To the extent that we are successful, we not only reduce the volume of pollutants entering the environment, but in certain instances we open up possibilities for bigger profits for processors. Bigger profits may result from process modifications that produce larger amounts of the primary food product, or they may result from the development of new or improved products from materials formerly disposed of as waste.

Whey utilization is a good example of finding more productive uses for a processing waste. Far be it from me to get into any of the details of whey utilization, but I think it might be worthwhile to bring you, through illustrations from other processing industries, some of the basic concepts that have been applied in whey studies. Several of these were developed by the Department's Agricultural Research Service and are already in use by industry. Others are just now ready for testing on a commercial scale. These illustrations are not inclusive, and in mentioning them I do not mean to slight many others that could have been cited from other sources. They are merely those that were readily available to us when we were putting this material together.

The first example we may cite is the new dry caustic method for the commercial peeling of potatoes. Peels are by far the largest pollutants of potato-processing plants which dump about a billion pounds of them into America's rivers and streams every year. The peels are carried in large volumes of water that are used to wash them from the potatoes after the peels have been softened in a lye solution.

From a pollution abatement point of view, the significance of the new process is that no water is used during the actual peeling operation. Hence almost none of the peel residue gets into the effluent from the plant. Instead, this residue is collected as a slightly damp material that could be burned, buried, or fermented and used in cattle feed. Some water is used before and after peeling, but the effluent from these operations can be treated by conventional means. The technique was originally developed for processing white potatoes, but it was also tested in Louisiana last summer on sweetpotatoes. It appears that it can be adapted for this purpose as well. It will also be tested on other products that need to be peeled.

While peels are the largest pollutants from potato processing, there are still others. One of these is found in waste materials from plants that make starch from potatoes. Research is being conducted at our ARS laboratory in Philadelphia on a method of disposing of this waste that would permit recovery of compounds that have a market value. Among these would be proteins, possibly fertilizer, an amino acid mixture, and even organic acid.

A new process has been developed for processing pickles that does away with vat fermentation. In the past, the brine used in fermenting vats has been the principal pollutant of pickle-processing plants. In the new method developed at Raleigh, N. C., the pickles are washed, flash-pasteurized, and put in jars with the brine and spices, along with a small amount of a pure culture of an organism that produces lactic acid. The fermentation occurs in the jars in which the pickles are sold, and thus the problem of brine pollution is eliminated.

Brine also creates problems in California's olive industry. It is estimated that nine of California's large olive-processing plants presently discharge more than 200 million gallons of briny waste every year. Scientists at Albany, Calif., have developed a new process for passing the processing liquid through columns of activated carbon and recovering the brine for re-use. The contaminants are held in the carbon. Then the carbon is cleaned in such a way that it does not itself become a pollutant.

We are also concerned with the peeling of tomatoes in the processing of tomato juice. A new system has been proposed for conducting almost all the processing in the field instead of in centralized canning factories. After harvesting, the tomatoes will be hauled to field stations where the pulp, skin, stems, leaves, and all other wastes would be separated. Wash water and solid wastes would be returned to the land where it could be disked under and utilized as part of the organic matter for the land itself. These substances are not pollutants under those circumstances. The juice is then taken in cans to central processing plants and converted into catsup, purees, and other concentrates. The only discharge from the central plant would be the pure water extracted from the juice itself. This is another means of avoiding large concentrations of processing wastes.

Let's turn to citrus juices, where it has been proposed that the waste-disposal problem might be virtually eliminated by the production of a whole-fruit drink. With this process, under development by our scientists at Weslaco, Tex., entire citrus fruits are ground up to make a puree base for juices and drinks. Only the seeds and the very toughest fibrous parts of the fruit are rejected as byproducts. About 85 to 95 percent of the fruit is used in making the puree, roughly 35 percent more whole fruit than is now being used to make citrus juices. The developers feel that this product would be competitive with synthetic artificially flavored drinks. Of course, there would be less waste materials to dispose of or convert into livestock feed.

Also in the citrus area, we have been concerned with the smoke that is discharged from pulp driers. The problem is critical for the orange industry in Florida, where about 92 percent of the orange crop is processed. Furthermore, of the total citrus crop that is processed, about 45 percent by weight is discarded as peel and cell membrane. In the past, plants have been able to convert this waste into useful dry citrus feed and molasses. But lately the problem has taken on new dimensions, as the total orange crop has increased and more of it is being processed. As more smoke has come from citrus feed driers, more complaints have been received from the residents of nearby housing developments. During this past season, Agricultural Research Service scientists at Winter Haven, Fla., began work on what they hope will be an eventual solution. They checked three of the current types of driers for effectiveness in controlling stack emission, as well as for overall heat efficiency and yield. One modern recirculation drier with a very high throughput was found to produce stack gases well below the Florida Board of Health standards. On the other hand, a conventional drier, with the usual liquid scrubber for vent gases, did not. Thus it is obvious that driers can be controlled in modern plants and that the driers in older plants can probably be modified without excessive cost to meet control limits.

We look finally at the wastes from soybean processing. Two methods are being studied for eliminating these wastes. One of them has to do with the alkaline solution that is used to wash out free fatty acids in conventional soybean oil processing. Refining plants have been disposing of about 150 million gallons of this wash water annually. An experimental process has been developed that passes the wash water through cation exchange resins. This treatment removes contaminants, permitting the same water to be used again and again. There is an added dividend in the form of a useful byproduct--soy fatty acids which can be recovered from the resin and sold for 5 to 10 cents a pound.

The second problem being studied is disposal of a milky solution called soybean whey. This substance is obtained as a byproduct when making protein concentrates and isolates. It is estimated that there are some 20 million pounds of solids in the soybean whey produced each year in this country. Some processors concentrate the whey and use it in feed, and others dispose of it. In the ARS laboratory at Peoria, scientists are working on a method that would make better use of the nutrients in this whey. Their method obtains substances from the whey that are high in tryptophan, lysine, and cystine, all of which can be used to upgrade the protein quality of food.

So we have reviewed a number of illustrations of ways in which processing wastes can be dealt with. Some have provided new useful products from the wastes, some have reduced the actual amount of the wastes produced. Of course, we are hopeful that these and similar pollution-abatement projects will have another significant effect--that they will result in an even safer, more abundant, and higher quality food supply for American consumers. But we must be careful, in formulating new ways to reduce processing wastes, that any modifications we make, or any new component we add, even for these purposes, will not affect man, animals, or plant life in any adverse manner. It would be ridiculous if, in trying to reduce pollution, we made some of the same mistakes that created the pollution in the first place.

Our research on processing procedures and their modification must include a study of their effects on food components. These components include the compounds naturally present that could have toxic effects, as well as those we propose to add in processing to improve the food's flavor, color, texture, or stability. We are already doing much work on the safety and effectiveness of food components, but it's still in a relatively early stage, and we must view it as an important part of our total research picture. Some of these food components are new; some of them have been used for centuries without any question as to their actual effect upon people. Often food components can affect such vital life processes as nutritional status and even disease resistance, but the effects they produce are not always immediately visible. Sometimes a disease or other disability builds up for a long time before it is recognized. Furthermore, once it is recognized, there may be further difficulty in pinpointing the component or combination of components responsible.

By their very nature, studies of this type must be long range and they do not lend themselves to simplification. Every component must be tested, checked, and rechecked. Every experimental approach must be continually re-evaluated to ensure that no side effects slip past undetected.

Finally, of course, as I have already noted, it's almost impossible to view our work--your work, any work in the area of agricultural research--in isolation. To be most effective it must be related to other food-processing studies and to many other factors that affect the entire environment. The energy, initiative, and technical know-how with which agricultural scientists have tackled past problems has made American agriculture the most efficient and productive in the world. We expect this to hold true in the years ahead. With renewed effort we can overcome any of the problems that are facing us now, whether they be disposing of waste from food processing, maintaining a wholesome and abundant food supply, or achieving safety balance and quality in the total environment. I wish you best success in your conference.

FEDERAL PROGRAM FOR ENVIRONMENTAL QUALITY

T. C. Byerly[1]
Assistant Director, Science and Education
U. S. Department of Agriculture
Washington, D. C.

On many accounts I am sorry Senator Nelson could not attend this conference. He has had a good deal to do with making people in the United States conscious of the problems of the environment and your industry is heavily represented in his State. In his place, I shall try to review for you the Federal programs that have to do with the environment. I shall identify some reference points, talk about some problems, and, hopefully, give some possible solutions.

I would like to begin by explaining my own position, as chairman of the U. S. Department of Agriculture's Executive Committee on Environmental Quality. Activities that have to do with the environment are major programs of almost all of the constituent agencies of the Department. Programs of research and development, technical assistance, financial assistance, and direct action are the responsibility of each of the agencies. The Executive Committee coordinates activities relating to the environment both within the Department of Agriculture and with other Federal departments and agencies. The committee meets to consider matters requiring its attention, or items are referred to individual members for action.

Some significant events have taken place with respect to the environment during these past few months. In his State of the Union message, President Nixon made a statement that I think epitomizes our concern as well as any. Amongst other things, he said, "We are concerned with the environment where each of us spends 80 percent of his time--in his home, in his place of work, and on the road to and fro." We are also concerned with other aspects of the environment not so close at home. The passage of the Environmental Policy Act, Public Law 91-190, was a landmark in the expression of this concern. It was instrumented by the issuance of Executive Orders, one of which, 11514, was addressed on April 6 to all of the executive agencies: "The Federal Government shall provide leadership in protecting and enhancing the quality of the Nation's environment to sustain and enrich human life. Federal agencies shall initiate measures needed to direct their policies, plans, and programs so as to meet national environmental goals. The Council on Environmental Quality through the chairman shall advise and assist the President in leading this national effort."

The Environmental Quality Council--now consisting of Judge Russell Train, Chairman, Gordon J. F. McDonald, and Robert Kahn--was created then, and has since been active as a coordinating mechanism throughout the government.

Now, I'd like to take another reference point, because there are some problems--and the problem of environment largely among them--that cannot be solved very well on a piecemeal basis. Having noted our concern, that of the

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[1] Dr. Byerly spoke for Senator Gaylord Nelson, of Wisconsin, who was unable to be present.

Federal Government and that of the President, let me note the concern of the world expressed through the Secretary-General of the United Nations. In his report he stated, "The land upon which man depends for his sustenance has been seriously impaired by many of his past activities, and in many areas this process continues. It has been estimated that 500 million hectares of arable lands have already been lost through erosion and salinization, that two-thirds of the world's forest area has been lost to production, and that 150 types of birds and animals have become extinct through human agency. Approximately 1,000 species or races of wild animals are considered to be rare or endangered. Erosion, soil deterioration, deforestation, watershed damage, and the destruction of animal and plant life continue, and in some areas are accelerated. The loss to mankind is of serious concern."

The deterioration of the human environment may thus be related to three basic causes: accelerated population growth; increased urbanization; and an expanded and efficient new technology with increasing demands for space, food, and natural resources. There is in prospect, with the support of this country and of the other countries in the United Nations, a world conference to be held in Sweden in 1972. The main problems to be discussed there have been identified by the Advisory Committee on the Application of Science and Technology as follows: (a) human settlement problems, that is, problems affecting local areas of human concentration for which action is primarily the responsibility of National governments and city and local authorities; (b) territorial problems, that is, problems of land areas, including also nonoceanic and coastal waters for which action is primarily the responsibility of National governments, but which also have regional aspects; and finally, (c) global problems, that is, problems of worldwide dimensions potentially affecting all countries and amenable to solution only by international agreements and the willingness of countries to act in concert for their common betterment.

Having given these broad statements and background of the discussion, let me come down to the here and now by mentioning an article published in the current (May 29) Science by Ralph Nash and Leroy Beall, of the Crops Research Division at Beltsville, Md. The abstract states the major environmental source of DDT (dichlorodiphenyltrichloroethane) residues in soybean plants arises from vapor movement from contaminated soil surfaces; in contrast, the presence of dieldrin, endrin, and heptachlor results primarily from root uptake and translocation through stems to leaves and seeds.

We are able to protect ourselves pretty well against the hazards we can foresee, but we tend to ignore the fact that there are unforeseen hazards. Our technology has not yet provided us with a good means of determining early in its adoption what all the hazards, direct and indirect, may be. Nor, for that matter, what all the benefits may be. For example, we hear a great deal about DDT, its global dispersion in the world and its accumulation in the eggs and young of fishes and birds, and its persistence in the environment. It is now 24 years since Dr. F. C. Bishop, then in charge of research in this area in the Department, walked into my office at Beltsville, where I was in charge of poultry research, and expressed his concern that DDT was secreted in milk and stored in animal fat. He thought we ought to determine whether or not it would be secreted in eggs when included in the feed. Dr. Max Rubin, Dr. Herbert Bird, and others undertook such studies and in 1947 published a paper in Poultry Science showing that, under the conditions of the experiment, up to several hundred parts per million of DDT were, in fact, stored in eggs.

Armed with knowledge that ingested DDT is stored in fat, we have managed pretty well to protect our food supplies against DDT, to keep it within safe limits as far as the human body is concerned, and to use this valuable pesticide in the protection of human health as well as crops in many areas of the world. But we did not know then that DDT vaporizes from the soil surface. Our soil analyses showed that although the insecticide was persistent, continual applications did not result in a build-up from year to year. And we were satisfied with that. But now it appears that DDT does vaporize in substantial amount and does circulate.

It's been perhaps 15 years since Lichtenstein at the University of Wisconsin published data indicating the translocation of organo chlorines in plants. But the amounts were so small, for the methods of analyses then available, that they could have been due to contamination. They weren't. It was not until about five years ago that Frear, of Pennsylvania State University, reestablished the fact that there is translocation of pesticides in these plants. We didn't know that. Our methods of analysis were then in parts per million. They have gone successively to parts per billion and parts per trillion. And DDT and some other pesticides exist in water in parts per trillion, generally. Parts per trillion are far below the criteria for drinking water. We did not then know, but we do now, that shellfish and bony fish, through gill filtration, can concentrate the parts per trillion up to parts per million in their body fat. Apparently the oyster, which is a very good concentrator, can purge itself when placed in water free of pesticides. Evidently the purging process in fishes and other animals is a much slower process. But what we most need to know are ways of determining the indirect impacts of our technology early in its adoption so that we can manage it and enjoy its benefits with a minimum of suffering from the hazards.

Our concern in the Federal government for people in their environment is not new nor, for the most part, is it novel. It is very great. Our concern is being focused by such events as the recent Earth Day, celebrated on our campuses last April 22. Here the concern of students and young people, as I have seen it, was largely on the people problems of the environment and rather less on the physical problems of the environment. When we talk about pollution, for example, we can identify the problems, and even come up with some of the remedies, far more easily than we can cope with the problems of people--of urbanization, of concentration, of technology, and of people's relationships.

During the past few weeks the National Academy of Sciences has issued Biology and the Future of Man, prepared under the leadership of the Academy's president, Dr. Philip Handler, with the participation of about 200 biologists, of whom I had the good fortune to be one. The book states that in the long run (a) population growth cannot continue indefinitely, and (b) if the major populations can be brought to an adequate level of education and technical achievement, the ultimate constraints to population growth will not appear until population becomes significantly larger than it is now. Such a world would probably find it desirable on humane and esthetic grounds to check its growth far short of the numbers that could be supported by a world economy continuing to develop and apply scientific knowledge. To such a world, knowledge of the human gene pool and of its potentialities for change should be of paramount importance, because in the last analysis man's destiny lies in his nature. There is no doubt that much of the seeming variability of mental, behavioral, and social traits can be accounted for by differences in nongenetic factors such as wealth and poverty, intellectual stimulation and its absence, or environmental encouragement and discouragement, as well as malnutrition in early life. A major task before mankind is to see that these nongenetic factors are adjusted, so that each individual realizes his genetic potential to the fullest.

In our quest for quality in the environment, we are seeking a nebulous goal in some ways, because there is no one optimal environment. There is no one place where each of us would prefer to be all of the time. We need diversity. We have different capacities. We have different needs, different wants. We need challenging environments, not homeostasis. We need no Elysian fields. We need to make sure that we introduce as few irreversible changes into the environment as possible.

Let us consider very briefly the resources that we have to deal with here in the United States and what we are doing with them. We as agriculturally oriented people are obviously concerned with the land. We have more than 600 million acres of land suitable for cultivation. In the last two or three years we have harvested crops from less than 300 million acres of that land. That's about 50 million acres less than we harvested 50 years ago. We have doubled our yields and, with increasing efficiency of technology, we can do it again. Production technology is of the utmost importance in protecting and enhancing the quality of the environment because of the resources it spares for other use. At the yields of 50 years ago, to produce our present annual harvest we would have to have 600 million acres, substantially all of our arable land. That other 300 million acres, which is now in grass, or trees, or put to other nonagricultural uses, is an area equal to the area of all the States east of the Mississippi River, south of the Ohio, and of the Mason and Dixon Line. It is important that we keep that land available, and we can.

The industrial nations of the world other than our own have moved in a similar direction and have cropland in the aggregate to spare. The developing nations have the opportunity, through the development and application of technology, of keeping their wildlands and their wildlife available for the future. They can if they will, but it is the costs of the technologies that we cannot ignore.

Of the great conservation agencies of the U. S. Department of Agriculture, I would like to mention the Forest Service, which manages our 186 million acres of National forest. Through multiple use, the Forest Service has been able to sustain the yield of trees and to increase that yield in time through wise management and through its research programs to uncover new ways in which all of us can benefit from our forests in the future. For example, Operation Sky Fire was initiated and carried on in Montana to study the nature of lightning storms. In that area there are a lot of dry thunderstorms in which the rain never reaches the earth, but lightning does, setting fires. The knowledge gained in Operation Sky Fire about the nature of storms and the effect of seeding at particular levels will be put to use in joint studies of hail suppression carried on by our own Department of Agriculture with leadership of the National Science Foundation and by the Environmental Science and Service Administration of the Department of Commerce with cooperation of Colorado State University and the other agencies in the area. This represents a challenge--challenge to improve the environment and manage it wisely, as far as weather is concerned.

In the Department of the Interior, the Bureau of Reclamation is charged with water supply, especially in the Western States. This agency is carrying on a bold and hopefully productive program to increase precipitation and water yield by appropriate seeding of clouds as they are lifted over the mountains to provide more moisture, usually in the form of snow, for storage and use in the Western States.

Man himself has affected climate. We talk about air pollution as a major factor, and it is. Our energy requirement has during the last 15 years shown a doubling time of about 10 years. Historically, our demand for electrical energy has been increasing at about twice the rate of our gross national product. Projected by the year 2000 the per-capita use of electric energy in the United States would be about 12 1/2 times what it was 50 years ago. That's an enormous growth in energy.

Now, let's consider this in terms of carbon dioxide. There was a period of time from about 1860 to 1940 when the world showed a warming trend. This was rationalized as the effect of carbon dioxide in the atmosphere and its mediation of the sun's activity. Since about 1940, there has been a cooling trend, and this is rationalized as extra particulates in the air, making low-hanging clouds and screening the world. So we are going downhill again. In the future man may be able to manage these factors so that he can have the weather the way he wants it, I don't know. We shall gain the technology. That I'm pretty sure about. What we shall do with it, and how wisely we shall use it, I am less sure about.

But there are things that are hopeful. We participate, through the Department of Commerce principally, in the World Weather Watch. We have Tiros satellites aloft to give us better weather projections. We are investigating the large storm and hurricane systems. As we learn about these systems, we may be able to do something about the weather. Again, it is very important in this formative stage that we study all the things that are implied by a capacity to control the weather. There is an Interdepartmental Committee on Atmospheric Sciences which meets monthly to discuss such problems as the impact of weather control on local people. What happens, for example, if I want rain and my neighbor does not? If rain comes at the wrong time on his crop and destroys it, who is responsible?

There are a few areas in which agriculture is a polluter. Among these areas, sediment is the biggest. We need more information, more research, on better ways of stabilizing soils and keeping the sediment out of our waters. Should we have to increase our area of cultivation, we will at the same time increase the sediment load into our reservoirs. A corollary of that, which is now a matter of some public interest, is the contribution of agricultural wastes and fertilizers to the eutrophication of our lakes.

Like our energy requirement, our use of nitrogen fertilizers has been doubling every 10 years, and it is now about 7 million tons per year. This looks like a lot of fertilizer, but we have not yet in this country, nor in the world as a whole, reached the peak of fertilizer use.

In the use of fertilizer in the United States, a rough balance is achieved by the more than 20 million tons of nitrogen lost from all sources by harvested crops, by volatilization into the air, by passage into ground waters, and by all other means, and the perhaps 20 million tons of nitrogen replaced by recycling from rain, by nitrogen fixation, by the return of crop residues and animal wastes, and by fertilizer application. The return does not quite balance out, however. When a field is covered with grass or growing crop, very little nitrogen is lost to water. But some does go into ground water when the land is not covered by a growing crop, is warm and bare, for any purpose, such as for cultivation, or as a result of fall plowing in warm weather, or of spring planting.

A third pollution problem stems from the concentration of animal feedlots. In the state of Colorado alone there are about a million cattle on feed in lots accommodating from 2,000 to 100,000 animals each. The feedlot steer will produce perhaps 50 pounds a day (wet weight) of urine and manure. Granted, in the dry Great Plains area, evaporation takes place fast, resulting in some weight reduction as volatilization of the material and bacterial activity take place. But if it is handled on an annual cleanout basis, the residue will amount to perhaps 20,000 tons a year at least. And the best solution, as far as I know, is still the old one of spreading it on the land in amounts that are useful as fertilizer. If excessive amounts are disposed of in this way, however, they will eventually be washed into the streams as the land freezes. I believe Wisconsin now prevents the spreading of dairy farm wastes on frozen soil because they do get into the streams.

This is a management problem, a problem for which our technology is still inadequate. Manure that is hauled away and put on land where it can be incorporated into the soil quickly is obviously put to good use. The transportation costs may not make it profitable, but it is a kind of solution. When the animal wastes cannot be thus quickly disposed of, however, our methods of accumulation--through holding basins, through dilution systems, or through digestion systems--are only temporary expedients. They aren't good enough. We have a need for more technology here. We need to build into our systems of dairy management, beef cattle feedlot management, and poultry management a better technology to handle this very large waste problem.

In the past few years some 80 million acres of land has been set aside for exclusive use as parks, as wilderness areas, as places of scenic beauty. Each year we are setting aside about a million acres for cities and airports and roads, and another million acres for nonutilitarian purposes. The million acres that go into cities and roads and airports are of some concern. About 65 percent of that so far has been cropland. We in this country have a permissive policy of land use. Even if we project that for the next 50 years two-thirds of a million acres a year will be converted from cropland to urban use, we are not concerned because our trends in production technology indicate that we can spare the 35 million acres. But sooner or later, it will catch up with us, and these changes are relatively irreversible. They are highly localized. Our population concentration is not very well matched with our natural resources. We have a half-dozen States that have lost population during the last year or two, and some will, apparently, continue to lose population. In other States, urban centers of population are so dense that people are trampling on one another's feet. Planning for assistance to States and communities with population problems is in the developmental stage. The policy here is highly permissive.

In conclusion, the quality of the environment is a concern of all of us. The Federal Government in its programs can provide assistance, but in the last analysis the kind of environment in which each of us will choose to live, and the opportunities we will have for choice, are up to all of us. The principal problem, in my opinion, is not the immediate one of too many people, but of determining how to protect ourselves from the unforeseen hazards of the future.

THE FWQA RESEARCH AND DEVELOPMENT PROGRAM FOR POLLUTION CONTROL IN THE DAIRY INDUSTRY

W. J. Lacy and G. Rey
Federal Water Quality Administration
Department of the Interior
Washington, D. C.

As an introduction it would be appropriate to quote President Nixon who said: "Private industry must take an active role in protecting the environment, providing recreational facilities, and conserving natural resources. Clean air, clean water, and unspoiled countrysides are more easily attainable through preventive measures than restoration and with a coordinated program for prevention, private industry can help lead the way to a better America."

Water Pollution Legislation

The Water Quality Act of 1965 provided for State water quality standards for the first time in Federal legislation. It also established the Federal Water Pollution Control Administration (currently renamed as the Federal Water Quality Administration). This was followed by transfer of the new administration to the Department of the Interior, and the enactment of the Clean Water Restoration Act in 1966. The latter provided not only a vastly increased authorization for Federal grants for construction of sewage plants, but also for research and demonstration of new or improved methods for municipal and industrial water pollution control.

As a result of the 1966 Act, the FWQA has established a research and development program for control of water pollution from the dairy industry. This discussion of the Federal program will hopefully indicate areas of mutual participation and cooperation by and between the Federal, State, municipal, and industrial communities.

The Federal program is unusual--perhaps unique in Government. It is a Research, Development, and Demonstration Program. It is a coordinated, problem-solving program which is dedicated to exploratory research of new and imaginative pollution control methods. It is a program which provides for the engineering development of these methods to solve the practical problems associated with bringing an "idea" out of the laboratory and into the real world. Finally it allows for the demonstration of this new technology to go that extra, normally neglected, step of showing the decision makers that new and improved technology has really arrived and may be implemented.

The program is highly mission oriented. Each of our projects responds to an identified need for an answer. These "needs" are identified and assigned priority primarily through input from the non-research elements of the FWQA and from industry. Briefly, we are trying to respond to the real needs of the Administration and the industry, and not just the needs which researchers believe to be important.

The program is unique since, for the first time, industry may participate in grants to develop and demonstrate new or improved methods of treating industrial wastes or otherwise preventing pollution. These methods shall have industry-wide application. Grants so authorized may not exceed 70 percent of the project cost, and are limited to a maximum of $1 million.

The Federal Water Pollution Control Act, as amended, also provides grants for projects which can develop and demonstrate "new or improved methods of jointly treating municipal and industrial wastes." Capital advantages are obviously possible in many cases if industries can discharge their wastes into municipal systems. Accordingly, the grants program represents a truly cooperative effort; it is a cost-sharing type of contract. However, in some cases the Federal Government bears the full cost of R&D by contracting with appropriate nongovernment entities for these services. Limited funds are available for this purpose.

Obviously with these tools the FWQA can support almost any related worthwhile project under almost any type of institutional arrangement. We have the means for sponsoring research, assisting pilot-scale developments, and participating in large, full-scale demonstration projects. To receive a grant, several conditions must be met. The project must have technical merit. There must be technical competence associated with the project, either as provided by the grantee himself or by consultants which he employs. Finally the project must fulfill an identified need. This means it must usefully demonstrate a way to combat water pollution. The results obtained must be accurate with respect to costs and performance, and they must be made available to the public.

Water Pollution Needs of the Dairy Industry

Let me define wastes momentarily as unusable resources of human industry. I say "momentarily" because all wastes have use in some time frame and in some ecosystem. The time frame is impacted by technology and need. I point out "unusable" because man does not willingly throw away his assets. Time, need, place, and technology then, all determine the scope of industrial waste problems. Yesterday's moldy bread is today's penicillin. Last month's papermill wastes could be in tomorrow's road-binding materials, cooking sauces, or medicinals.

We recognize that industrial wastes are the nation's principal sources of controllable waterborne wastes. In terms of the generally quoted measurements of strength and volume, the gross wastes of manufacturing establishments are about three times greater than those of the nation's sewered pollution. Moreover, the rate of industrial production, which gives rise to industrial wastes, is increasing at about 4.5 percent a year, or three times faster than the population. Add to this the extensive variations in composition of industrial wastes, and you realize that the solution to industrial water pollution control is not a simple one.

Based upon estimates of the "average" quantity of pollutant produced per manufactured product unit, the indications are that the chemical, paper, and food industry groups generate about 90 percent of the BOD_5 in industrial wastewaters before treatment (1). The dairy industry is only one of several major subclassifications of the food industry.

Systems for handling combined municipal and industrial wastes in many cases are likely to provide the means of attaining adequate water pollution control most effectively and least expensively. The extent to which these joint handling systems will increase over the next five years will depend largely upon the managerial ability of municipal and industrial officials and their willingness to enter into cooperative arrangements. It will also depend on the compatibility of the wastes for joint treatment. The costs which industrial establishments are required to pay to use municipally operated facilities will also be a factor. Assuming appropriate charges, establishment of pretreatment requirements, and effective design and operation of joint treatment facilities, the use of such facilities by industry may well lower overall pollution control costs significantly.

Some large industrial plants in the United States treat their wastes economically. However, the use of the same technology may not be economical for the treatment of wastes produced in similar but smaller plants. At present, some small plants discharge their wastes to the community sewer system and depend upon the municipal sewage plant for the treatment. But some plants do not have sewer systems readily available. Furthermore, appropriate systems for some industry wastes have not been developed yet. It is thus imperative that methods for the treatment or control of wastes be developed where necessary by industry, considering the following:

1. Many municipal sewage plants are overloaded and sensitive to strong and toxic industrial wastes, and thus may be forced to restrict the types of industrial plant wastes discharged untreated to the sewage system.

2. Certain industrial wastes may well be an undeveloped national resource, as wastes often contain valuable byproduct materials, some of which could more feasibly be recovered than treated.

Ideally, a process for treating wastes from an industry should:

1. Effect the removal of the pollutant at minimum cost.

2. Provide for the economical recovery of any valuable byproducts.

3. Be a technique that would permit the recycling of recovered materials, including water, back to the production operation.

4. Be simple and require minimum operating labor.

5. Require relatively low capital investment.

As a minimum, wastewater treatment and control facilities having a current replacement value of at least $5 to $6 billion must be utilized to achieve, by 1973, the level of industrial waste reduction and temperature control assumed to be necessary to meet water quality standards. Roughly half the value of the necessary investment is presently provided by industrial waste treatment and cooling plants in place, or by municipal facilities which treat industrial wastes. But an investment of nearly $2 to $3.5 billion will be required to overcome the accumulated deficiency in industrial waste treatment facilities that now exists; another $0.5 to $1 billion, exclusive of depreciation, will be required to keep pace with industrial growth to 1973. The annual cost of operating and maintaining these systems is expected to rise from

$0.5 billion to over $1 billion, exclusive of depreciation by 1973.[1]

Reduction of industrial wastes is often accomplished efficiently and economically by process modifications and improved housekeeping. The quantities of water consumption per unit of production have been decreasing in most industries as a result of increasing water use efficiency by recycling treated wastewater, by multiple use of water, or reduction of water usage. Modern operational practices and engineering design increasingly stress waste control by these methods of efficient water usage. The industry should not overlook the importance of good housekeeping.

The Federal industrial R&D program has as its general objective to help provide each major industry the demonstrated, developed, and evaluated technology for the abatement or prevention of water pollution from individual or multiple wastewater sources. With this in mind, what is the program doing about the dairy industry's contribution to water pollution?

To answer the question, let us take a look at the dairy industry. In 1968 an Industrial Waste Profile of the Dairy Industry (2) was prepared by the Federal Water Quality Administration. A summary of the findings and conclusions are shown in Tables 1 and 2.

TABLE 1.--Dairy pollution profile(1968)

Source of waste	Gross wastes before control (million lb. BOD)	Net wastes to waterways (million lb. BOD)	Pollution control effectiveness (pct. of gross)	Conclusion
As product	136	47	65	Improve housekeeping
From soap and chemicals	14	5	64	Insignificant contribution
From cream, skim milk, buttermilk	3,782	334	91*	Efficient recovery Upgrade all plants**
From whey	627	251	60	Inefficient recovery or use
Totals	4,559	937	80	Can be improved substantially

*Average of all plants.
**New and well-managed plants obtain pollution control effectiveness up to 99 percent.

From the data of Table 1 it can be concluded that pollution control of whey leaves much to be desired. Considering the characteristics of whey and the fact that some wheys are currently marketed as byproducts of cheese manufacturing, we can conclude that much greater utilization of whey should be accomplished. Accordingly, the Federal program emphasizes this aspect more so than any other approach as a solution to the pollution problem of the dairy industry.

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[1] Based upon U. S. Department of Commerce, BDSA 1963 Census of Manufacturing data.

These summaries strikingly indicate the need for high-priority R&D in the treatment, recovery, and utilization of whey from cheesemaking operations.

TABLE 2.--Byproduct use of dairy wastes (1968)

Waste	Percent utilized	Conclusions
Skim from buttermilk mfg.	91*	Efficient utilization in effect or readily attainable
Buttermilk from butter mfg.	91*	
Cream from cheese mfg.	99	
Whey from cheese mfg.	53	Improvements needed

*Average of all plants. New and well-managed plants can obtain up to 99 percent utilization of byproducts.

Whey Pollution Control Technology

Early in 1967 the U. S. Department of Agriculture assembled a task force which submitted an unpublished report on the research needs on whey and whey utilization. In February of 1969 Weisberg and Goldsmith (6) published a paper, "Whey for Foods and Feeds," which was a proposed solution to whey pollution control through the beneficial utilization of whey. Other studies (3, 4, 5) also were helpful in formulating an approach to the problems.

From an R&D point of view, the aforementioned recommendations pertinent to pollution control made by these authorities are summarized as shown in Table 3. Considering that it is inevitable that some raw and deproteinated whey will probably always need to be treated, biological treatment technology should also be made available to cope with some of the whey problems. However, it is obvious from the opinion of various experts that the more plausible approach to whey pollution control lies in its conversion to a dry stable material suitable as a byproduct for either human or animal consumption.

Based on economic and marketing considerations it would be preferable to see whey enter the human consumption market where it has already demonstrated some successful history (6).

TABLE 3.-- Status of whey pollution control technology

Technology	Need for:			Application
	Research	Development	Demonstration	
Biological treatment (joint treatment systems)	--	Some	Yes	1. Product losses 2. Rinse waters 3. Deproteinated whey treatment
Spray drying of whey	--	Some	Yes	1. Raw wheys 2. Improved economics 3. Cottage cheese whey drying
Concentration and fractionation of whey	Yes	Yes	Yes	1. Small plants 2. Rinse water 3. Deproteinated fraction for sale
Fermentation for production of byproducts	--	Some	Yes	Alternative to bio-oxidation treatment, if feasible
Regionwide comprehensive pollution abatement plan	Yes	Yes	Yes	1. Regional collection 2. In-plant cheesemaking procedures 3. Economical venture

Cheese Plant Wastes

Cheese plants produce wheys of different characteristics. The acid wheys, from cottage and cream cheese manufacturing, are substantially different chemically from the sweet wheys resulting from the manufacture of such cheeses as Cheddar and American. The difference is so great that until recently practical methods of drying acid whey were not in use, while several commercial processes were available for drying sweet whey to a powder suitable for human or animal consumption. In addition, the raw wheys can be handled more economically than dilute whey rinse waters. Nevertheless, rinse waters are also of concern although they may only contain a fraction of the total whey solids produced from any one cheese operation (normally 10 percent or less).

In addition to the type of whey and the rinse waters, we must also contend with the problem of plants too small to economically undertake a whey byproduct recovery operation of their own. For plants of this nature some tools need be provided to assure that a pollution plan can be implemented at some reasonable cost and at some appropriate time.

Accordingly, high program priority has been placed on R&D activities related to pollution control of acid wheys, sweet and acid whey rinse waters, and wheys from small dispersed cheese plants.

Federal Water Quality Administration Projects

As a result of these analyses, and with the help and counselling of the U. S. Department of Agriculture and other Federal agencies and knowledgeable people in the industry as well as the industry itself, we currently have a half-dozen projects underway to develop solutions to the whey problem confronting the dairy industry.

Table 4 is a listing of these projects. As you will note, the costs involved totals in excess of $7 million with FWQA participation at nearly $2 million.

Also please note that the majority of the projects listed are demonstrational in nature. This is fortunate, and reflects the fact that much of the basic research has been done in the past. Credit for much of the past work should be given to the U. S. Department of Agriculture, where basic research on whey utilization and on methods for recovery of food components from whey are currently continuing.

Conclusions

In conclusion, our current program strongly emphasizes the conversion of whey to a stable nonpollution-type product because we recognize that whey is a resource to be fully exploited rather than destroyed or disposed of without benefit.

The pollution abatement plans that will need to be complied with by cheesemakers in the near future leave them only two choices for continuing operations: treatment for disposal or recovery for use. In the past, the

TABLE 4.--FWQA R&D grants for whey pollution control

Grantee	Total estimated project cost	FWQA grant	Primary effort			Type of Whey	Area of technology and/or pollution control method
			Research	Development	Demonstration		
Dairy Research & Development	$2,499,038	$ 551,350	--	Some	Yes	Acid	Conversion of raw acid whey to stable spray-dried, food-grade whey.
Walton, New York	80,047	52,730	Yes	Yes	In pilot only	Acid	Activated sludge and trickling filter applications, whey rinse waters.
Ohio State University	18,505	12,954	Yes	--	--	All	Technology status of dairy plant wastes and treatment methods.
Crowley's Milk Co., Inc.	914,081	495,856	Some	Yes	Pilot and prototype	Acid	Ultrafiltration and reverse osmosis as methods for concentrating and fractionating whey.
Kent Cheese Co.	67,723	46,006	--	Yes	Yes	Sweet	Aerated lagoon treatment of whey rinse waters.
State of Vermont	3,700,000	823,120	Yes	Yes	Yes	Acid and sweet	State-wide comprehensive whey pollution abatement plan from all cheese plants, with byproduct conversion of whey.
TOTALS	$7,279,394	$1,982,016					

choice has been between disposal and recovery, with recovery a marginal (if not profitable) economic operation. Now it should be concluded that whey recovery as a means of complying with water pollution control requirements should be even more economically encouraging. We, therefore, believe the FWQA program currently underway is timely, comprehensive and responsive to the need of the dairy industry in that it is orientated to demonstrate new and improved technology and/or methods for the control of pollution resulting from whey.

Discussion

QUESTION: Are reports on FWQA projects available?

ANSWER: Final reports will be available on all projects. Interim reports are not normally available. You can put yourself on the mailing list by writing to Project Coordination, Federal Water Quality Administration, U. S. Department of the Interior, Washington, D. C.

Literature Cited

(1) Anonymous.

1968. The Cost of Clean Water. Vol. 1, "Summary," U. S. Department of the Interior.

(2) Anonymous.

1968. The Cost of Clean Water. Vol. 3, "Industrial Waste Profiles, No. 9-Dairies."

(3) Arbuckle, W. S., and Blanton, L. F.

[n.d.] The Development, Evaluation and Content of a Pilot Program in Dairy Utilization, Dairy Waste Disposal and Whey Processing. (Program conducted in 1966 and 1967.)

(4) Fife, C. L., and Nelson, K. M.

1969. Production, Disposal, and Use of Whey in Vermont. University of Vermont Bulletin 658.

(5) Groves, F. W., and Groff, T. F.

1965. An Economic Analysis of Whey Utilization and Disposal in Wisconsin, University of Wisconsin Agr. Econ. Report 44.

(6) Weisberg, S. M., and Goldsmith, H. I.

1969. Whey for Foods and Feeds. Food Technology 23: 186-190.

WHEY PROBLEMS OF THE CHEESE INDUSTRY

R. F. Anderson
Executive Secretary, National Cheese Institute
Chicago, Ill.

The theme pollution or utilization implies a choice. I have not heard nor seen anyone opting for pollution, so it is apparent that the choice of the alternatives is utilization. Webster says "utilization" is to "turn to profit." This idea in itself should motivate your interest in this conference. In researching for this part of the program and in an attempt to be faithful to the title assigned by Dr. Senti, I was impressed with the nature and diversity of the problems confronting the cheese industry, as far as whey is concerned.

First let's identify whey--from 10 pounds of milk there are approximately 9 pounds of liquid whey for each pound of cheese produced. The liquid whey, after separation, contains about 7 percent solids. These solids consist of approximately 4.9 percent lactose, 0.9 percent protein and 0.5 percent ash.

Recent U. S. Department of Agriculture statistics show that about 22 billion pounds of fluid whey are produced in this country annually. There is every indication that this figure will increase. Statistics also show that about a third of this whey is now used in food or as a supplement to animal feeds. So the immediate problem, and the theme of this conference, is the utilization of the other two-thirds, or about 14 3/4 billion pounds of whey. The questions facing the cheese manufacturer are: Should he process the whey himself, or ship it off for processing, or must he reluctantly contribute to the growing waste-disposal problem?

It is of interest to consider where this whey is located. We don't have "whey production" data by States, but last year about one-half or nearly 600 million pounds of the over 1.2 billion pounds of Cheddar-type cheese produced was made in Wisconsin. Of the other major cheese-producing States, Minnesota contributed 105 million pounds, Missouri 83 million, Iowa 71 million, Kentucky 58 million, and New York 42 million. U. S. Department of Agriculture reports go on to show that cheese is produced in 33 States. You can be assured that the cheese industry in these States is vitally interested in the challenges of whey utilization and the growing concern about pollution.

In the past the usual recommendations of State agencies regarding the handling of whey have been one or more of the following:

1. Use for animal feeding in its original form.

2. Condense or dry for recovery of whey solids or lactose for food or animal feed uses.

3. Dispose on land in a remote place where nuisance or water pollution (surface or ground) will not occur.

The first suggestion, to feed animals liquid whey, has had limited success. Today it is becoming more difficult to deliver liquid whey to the farmer, especially as the number of small cheese plants declines and the increased production is concentrated in larger, more efficient operations. State laws prohibit the use of milk cans to return whey to the farm, with the result that whey accumulates at the plant for pickup by the farmer. The growing trend is that fewer farmers are inclined to go to the trouble.

The second suggestion, to recover the whey solids, is the objective and hope of this conference. New and promising uses and techniques for handling whey are predicted. However, to the small cheese factory the problem associated with this suggestion is the initial cost of equipment and facilities. To justify the $7,000 to $10,000 expenditure for the minimum processing equipment, the plant should be producing at least 100,000 pounds of whey per day. This would permit the plant to roller dry the whey at a cost of approximately $4.00 per hundred pounds of whey powder.

The third suggestion, to spread the whey as a fertilizer, has its own built-in limitations, because the suggestion goes on to warn against the practice if it would be a nuisance or a water pollutant. Nevertheless, whey has value as a source of plant nutrients. A ton of liquid whey contains about three pounds of nitrogen, 3/4 pound of phosphorus, and 3 1/2 pounds of potassium, plus small quantities of sodium, calcium, magnesium and chlorine. Whey will improve soil structure, make the soil easier to work, increase water infiltration, and thereby reduce soil erosion. Maximum benefits from whey result when it is applied on a nonlegume crop such as corn or grass. A total application of 100,000 to 200,000 pounds of whey per acre has been suggested. One acre-inch is about equal to a 100-ton (200,000 pounds or 25,000 gallons) application. If a farmer has available equipment to haul and spread whey, then it can be put to good use as fertilizer.

The cheese plant does not benefit directly from this recommendation beyond having a place to dispose of excess whey. Furthermore, whey disposal is a day-by-day, year-long problem for the plant, and a need for fertilizer is restricted to the beginning of the growing season. The cost of hauling whey to a dump, if one is available, has been estimated to be about 4¢ per hundredweight.

On the other hand, a cheese factory can't just put the whey down a hole and forget it. Although one plant did try. In gathering facts for this presentation I asked many operators for their experiences with whey disposal. One story that exemplifies the ingenuity and cunning used to cope with the problem went like this: Situated on the property of one plant was an abandoned well, drilled deep into limestone. The owner decided this was the ideal place to discard surplus whey. He did so for several years, until shortly after we became engaged in World War II, when the rafters of the plant were shaken by an explosion. The plant owner knew that cheese was a valuable food and essential to feeding the troops, but he felt it was ridiculous for the enemy to bomb a cheese factory in the middle of America! What had happened was that the whey, trapped and under pressure, had finally developed enough gas to blow the top of the well sky high. In short -- where there's a well there's no whey!!

The cheese industry is increasingly concerned over the types of pollution that detract from the quality of environment. Ecologists warn that one of the most urgent challenges now facing mankind is to halt and reverse the growing deterioration in the environment.

Growing populations, more affluence, and the increasing rate of industrialization and urbanization are producing a series of waste disposal problems for society which arise from the interplay of advances in science and technology.

Until the industrial revolution there was little or no interference with nature's self-regeneration. It had the ability to make the necessary adjustment. Almost all waste, including whey, decomposed or acted as nutrient or raw material for other forms of life. Since World War II, the problem of pollution has assumed greater proportions. Every day new products enter the market. The wastes from some of these developments are virtually indestructible and cannot be readily integrated into the natural cycles of our environment.

The major sources of water pollution may be classified as: municipal, manufacturing, mining, steam electric power cooling, and agricultural. Water pollution is said to be present when the water contains excessive amounts of any of the following: domestic sewage, infectious agents, plant nutrients, organic chemicals (pesticides, herbicides), other mineral and chemical substances, radioactive substances, or heated discharge water.

I mention these conditions to put the problem of whey disposal in its proper perspective. The total problem is the cumulative effect of all these components of our expanding society combining to upset the balance of nature. Pollution control is a community effort involving industry, government, and the public.

Whey, if discharged into a waste disposal system, becomes a part of the domestic sewage that includes human and animal wastes, vegetable matter, and the wastes from canneries, dairies, meat-packing houses, and other food processors. These particular wastes reduce the oxygen content of water. This oxygen is not only needed to sustain aquatic life, it is also needed to kill harmful bacteria and to purify the water.

There are three levels of wastewater treatment in use today--primary, secondary, and tertiary. Primary treatment consists of removing the larger solids by screening and the finer ones by settling, which produces a sludge. The sludge is decomposed by bacteria. This primary treatment removes about 40 percent of the oxygen-consuming pollutants.

The secondary treatment uses special microorganisms to further digest the sludge. After the first and second treatment most of the oxygen-demanding pollutants are removed.

The tertiary treatment consists of special measures such as oxidation ponds. These are outdoor sewage lagoons where microorganisms do their work, assisted by fresh air and sunshine.

Many of the communities in which cheese plants are located have only the primary system. It is difficult to handle whey in a single unit and therefore many municipalities refuse to accept it into their disposal system.

The problem of disposing of whey into streams or into sewage treatment plants is its high biological oxygen demand (BOD) caused by the protein and carbohydrates in whey. It has been estimated that the BOD represented in 100 pounds of whey is equivalent to the waste produced by 21 people every 24 hours. In other words, a cheese plant producing 100,000 pounds of whey per day requires a treatment plant about the same size as the principality of Monaco, a city with a population of about 22,000.

In a more significant light, the dumping of whey into a disposal system as a waste is a loss to the world's food supply. We are approaching, if not already encountering, the problem of providing additional nutrients for the expanding world population. It is apparent therefore that the whey problems of the cheese industry should not be ones of disposal. The challenge is to ennoble whey and utilize it--and utilization stems from research and development. New ideas, new innovations must be encouraged and protected.

I am convinced that there is one deep-down nagging problem confronting whey processors. Useful products derived from whey are threatened with extinction before they begin. Markets developed in this country are no sooner started than they are threatened by or lost to imports.

As an example, in 1968 only 374,000 pounds of lactose were exported to this country. Domestic production was roughly 83 million pounds--more than double the 39 million pounds reported 5 years earlier in 1963. However, last year over 4 million pounds of foreign lactose had been landed, and this year the average receipts have been over 400,000 pounds per month. Each pound displaces domestically produced lactose derived from whey, and thereby United States manufacturers of lactose are being injured.

Lactose is classified in the latest edition of Tariff Schedules of the United States (TSUS) as Item 493.65 - Polysaccharides, Schedule 4--Chemicals and Related Products, part 13. There is no quota on lactose but there is a 14 percent ad valorem duty.

Lactose is important to whey utilization. What is happening to lactose would probably happen to any other domestically produced product derived from whey that this conference suggests. We ask your help in solving this problem which, in the final analysis, has a profound influence on the implementation of whey utilization projects.

One remedy for disruption of the domestic dairy products market was provided by Congress in Section 22 of the Agricultural Adjustment Act. Unfortunately, as now interpreted, this section does not provide protection for all dairy products. The interpretation used by the U. S. Department of Agriculture has already caused the extinction of the domestic casein industry. Other segments of the dairy industry, in particular the modified whey industry, are in danger if the law is not interpreted differently. The dairy industry asks for your help in our efforts to have a new look at the past interpretations.

Section 22 provides the basis for mandatory action as follows:

> "Whenever the Secretary of Agriculture has reason to believe that any article or articles are being or are practically certain to be imported into the United States under conditions and in such

> quantities as to render or tend to render 'ineffective,' or materially interfere with, any program or operation undertaken under this title or the Soil Conservation and Domestic Allotment Act......, or to reduce substantially the amount of any product processed in the United States from any agriculture commodity or product thereby with respect to which any such program or operation is being undertaken, he shall so advise the President, and, if the President agrees that there is reason for such belief, the President shall cause an immediate investigation to be made by the U. S. Tariff Commission....." "If,...., the President finds the existence of such facts, he shall by proclamation, impose such fees,...or such quantitative limitations....as he finds and declares to be shown by such investigation to be necessary...."

It appears from the criteria of Section 22 that the necessary showing of material interference for any product of milk was that imports had increased and production had decreased.

This is precisely what is happening to lactose. The price effect of imports at 2 to 3 cents under domestic prices is great enough to cause declining domestic production. This should be considered material interference.

The problem arose when the U. S. Department of Agriculture considered "interference" to be applicable only to those products under price supports: butter, nonfat dry milk, and Cheddar cheese.

The cheese industry has battled long and hard to bring other varieties of cheese under quota. For example, it was not until 1967 that the Department finally agreed that cheese is cheese and one pound of imported Colby could replace one pound of domestic Cheddar. Next July 7 the Tariff Commission will hear testimony on four nonquota items--ice cream, chocolate crumb, milk replacer feeds, and skim milk cheese. Lactose was not included on the agenda, so it seems lactose production will continue to be threatened.

The present quota system, which is administered under Section 22 proclamations, is an improvement over the chaotic trade conditions that could exist. Nevertheless, loopholes and evasion tactics persist. A fairer system of administering international dairy trade is needed, a system that recognizes not only the interest of the exporter but the very real need for the domestic producer to have an indication of the volume of imports to expect.

We ask for your consideration and support of the proposal to ask the President to use the authority of Section 22 to describe any article as he shall determine. Instead of assigning quotas on the basis of product name, we ask that the President:

1. Set an overall milk equivalency for dairy product imports consistent with the aims of the dairy support program and the needs of international trade.

2. Reconfirm the quotas already assigned to specific dairy products and deduct these volumes from the overall milk equivalency figure.

3. Consider the unassigned milk equivalency volume as a bank account on which foreign dairy product exporters could draw. The use of the unassigned volume should be equitably distributed in the interest of fair trade.

We believe that this interpretation of Section 22 more faithfully represents the intent of Congress. It would relieve some of the problems associated with the classification of dairy products, encourage profitable dairy production in this country, provide domestic producers with protection as they develop new products, and reduce the drain on the treasury for the dairy support program. In addition, it would provide a basis for meaningful international trade, with both the importer and exporter advised in advance of the volume of dairy products available.

The whey problems of the cheese industry are many and varied. It is obvious that they range from "whey disposal" to "whey utilization." We look forward with interest to the recommendations of this conference. We also ask for your support and understanding when industry attempts to put into effect those recommendations.

Discussion

QUESTION: What are the possibilities for whey acidification, and how will that affect the programs that are being developed at this moment?

MR. ANDERSON: I suppose you are talking about cottage cheese whey, and we don't represent cottage-cheese manufacturers.

MR. WARD: We've had some experience with acidified cottage cheese whey, and it's a better quality whey than the conventional product. So I don't see any problem. I would say it probably has more potential applications and uses. It has a better flavor. It is very bland. It has a little more lactose in it than conventional whey.

COMMENT: There is very little difference between acidified cottage cheese whey and casein whey.

COMMENT: By electron membrane processes one can de-acidify whey if need be.

Theme: Whey Processing

Chairman: S. R. Hoover, Asst. Deputy Administrator, Marketing & Nutrition Research
Agricultural Research Service, USDA
Washington, D. C.

INDUSTRIAL PROCESSING OF WHEY TODAY

K. W. Ward
Foremost Foods Company
San Francisco, Calif.

Just as a man is the lengthening shadow of a child, so does an industry reflect its early beginnings. We might first review some of that history as a prelude of the whey industry today.

Whey, the serum of milk resulting from the removal of fat and casein from whole milk, is a greenish-yellow liquid. It contains roughly half the solids of the whole milk from which it is derived and most of the water-soluble vitamins and minerals.

A typical analysis might be (in percent): Total solids 6.3, lactose 68-72, protein 12-13, minerals 8-9, plus small amounts of fat and lactic acid.

At one time considerable quantities of casein whey were developed in the United States, but price support programs favoring the production of nonfat milk made it impossible for the casein manufacturer to compete. Practically all raw whey produced in the United States today is of two general types: low acid whey from Cheddar, Swiss, and Italian varieties and high acid whey from soft cheese, of which cottage cheese is the predominant type.

This year the cheese industry will produce about 22 to 23 billion pounds of whey. The center of the industry is Wisconsin, although sizable cheese operations exist in New York, Illinois, Missouri, California, Minnesota, Ohio, Iowa, Kentucky, and Tennessee. This is the equivalent of roughly 1,400,000,000 pounds of whey solids. Somewhat less than half of this will be processed, a ratio that hasn't changed appreciably in the last 15 years.

Originally most cheese whey, particularly in the hog belt, was returned to the farm for stock feeding. This has persisted to this day but on a greatly reduced scale. In most areas bulk tanks and sanitary regulations have eliminated the practice.

It is therefore not surprising that early efforts to manufacture whey were directed to the casein plants. The nature of the process was such that large quantities of whey were already centralized without additional hauling expense.

Early methods of concentrating and drying whey used the Simmons, Buffalo-Vac, Peebles, and also the conventional standard hot roller milk driers. The Simmons process concentrated whey to very high solids and allowed the mass to cool and solidify until it could be extruded on trays and dried in a tunnel. Buffalo-Vac employed a steam-heated, two-stage,double-drum configuration, with the upper drums acting as a high concentrator and the final drying being carried out on the lower drums. Peebles used a combination of spray drying and rotary drum drying where stability was achieved through the addition of whey concentrate, much in the same manner as the modern pill machine functions. Hot rollers of the milk type could be used only on fluid whey or whey at relatively low concentrations.

Needless to say, none of these early processes were particularly efficient and the infant industry made little progress. Its inability to solve the problems of high manufacturing costs, hygroscopicity of the dry product, and the general effects of the Great Depression seemed to be insurmountable obstacles. Then, about 10 years after the first fumbling efforts (in 1925) two important developments took place: First, the development of the long-tube, multiple-effect evaporator and second, the invention of the hydrate spray dryer by D. D. Peebles.

The long-tube, multiple-effect vacuum evaporator was the first significant development in whey processing. This type of evaporator was first used for whey processing in 1933 and provided a unit having high capacity, low operating cost, and relatively low investment per unit of capacity. It provided a tool by which large quantities of whey could be condensed quickly and efficiently into manageable form, either for immediate drying or transfer to a centralized drying plant.

The invention of the hydrate spray dryer was the second significant development in whey processing. Spray drying as a process was relatively new in the 1920's having been pioneered by C. E. Gray and Aage Jensen for the drying of skim milk. Ordinary spray drying, as practiced at that time, provided an anhydrous powder which, because of its hygroscopic nature, was unstable and caked very rapidly unless carefully protected from the air and moisture.

The hydrate dryer, developed by D. D. Peebles and patented in 1937, was of great importance in the processing of whey since it provided a simple and rapid method of producing a stable, nonhygroscopic, noncaking product. In this drying process, high-solids whey concentrate obtained from the conventional concentrating step is spray dried in a desiccator to a free moisture content of 12 - 14 percent. At this moisture content lactose takes on a molecule of water and crystallizes into the alpha-monohydrate form. This causes whey solids to convert from a sticky, syrupy-like material into a damp powder with good flow characteristics. It can be removed from the drying chamber and subjected to further drying in a rotary drum or vibrating tray dryer to reduce the free moisture. This produces a stable, nonhygroscopic, free-flowing whey powder, with lactose in its hydrated form. In addition to providing a stabilized, free-flowing and noncaking whey product, this type of dryer, operating with a rotary atomizer, provides high-capacity drying and lends itself to a centralized drying operation.

Armed with these tools, the Western Condensing Company, a California company and a predecessor of the Foremost Food Products Division, expanded rapidly, first to New York State, then into Wisconsin, and from there to all of the major cheese-producing areas in the United States.

Lactose, the major constituent of whey, had long been produced for the pharmaceutical industry. Then came the first antibiotic. Three small lactose manufacturers were ill prepared for the demands placed upon their facilities by the discovery of penicillin during World War II. Western Condensing took up that challenge, developed a process for the removal of lactose from cheese whey, and by the end of the hostilities was providing most of the lactose required for penicillin fermentation. After the war, expansion of lactose facilities continued. Its use in penicillin virtually ended in the early fifties but other outlets have dwarfed this early market.

Until well after World War II all whey solids, with the exception of lactose, had been marketed in feed channels. There were two popular forms: Dried powders of varying stability and condensed forms in either blocks or barrels. Whey for edible purposes appeared on the market in the early fifties and a standard for dried edible whey was promulgated by the USDA in 1954. Whey and whey blends started to push into bakery products and then into other foods, such as candy and dry mixes.

The next significant development was the demineralization of whey through electrodialysis. Unlike the ion exchange system, demineralization could be stopped at any desired point. This made possible the manufacture of a great variety of demineralized products with almost any range in lactose, protein, and minerals.

Growth in the edible markets and centralization of the cheese industry into larger factories has greatly changed the whey processing facility of today. Because of constantly increasing cost of transportation, more whey is being concentrated at the point of origin. It is then either dried at the same location or trucked to a central plant for further processing and drying.

The more modern whey plants are quite comparable with the best milk powder plants:

Buildings are of masonry and of sanitary construction.

Stainless steel (304 or 316) is used throughout on the product surfaces of the processing equipment.

Multiple-effect, long-tube evaporators, either of rising- or falling-film type, are used extensively.

The spray dryer, many of the conical type and usually with secondary drying, is the standard of today.

Transportation equipment and, in fact, all appurtenances are identical to that used in the manufacture of milk products.

For edible whey production, care of the raw product starts at the cheese factory. In most cases the whey is cooled, stored in insulated stainless steel tanks, and transported in sanitary tankers.

Whey Processing Used Today

In processing dried edible whey, the fluid whey is first pasteurized and then evaporated in multiple-effect evaporators, followed by further concentration in a single- or double-effect concentrator, and finally spray dried as a stabilized, hydrated whey powder, and packaged in poly-lined multiwall bags.

In the production of lactose, there are two main processes in general use today. The first is the so-called M & R Process in which the whey protein is chemically solubilized, permitting concentration to higher than normal levels. The concentrate is cooled to effect the crystallization of lactose which is then separated by centrifugation and air-dried prior to packaging. The product is of relatively high purity and suitable for infant food and other related products. The process provides a high yield with a single crystallization step.

The second process represents the more conventional method in which whey is concentrated to somewhat lower levels but without chemical solubilization of the protein. The concentrate is cooled to effect the crystallization of lactose which is then separated in conventional centrifuge equipment and finally air dried as a crude lactose. The crude lactose is refined by decolorizing and filtering procedures similar to those practiced in the sucrose industry. Products of very high purity can be produced by this method, including, U.S.P. Grade, and it is suitable for all applications.

The most recent major development in whey processing has been the use of electrodialysis in the demineralization of whey. Early efforts in demineralization of whey by ion exchange were not commercially feasible due to the cost of regenerates and their subsequent disposal, sanitary problems, and the necessity of working at low solids concentration. With the development of the permselective membrane by Ionics, Inc., in the fifties, it became possible to develop equipment and processes which could economically demineralize whey to any desired level and at acceptable capacity.

The achievement of a commercially feasible demineralization process, along with previously developed processes for the removal of lactose and protein, has made it possible to fractionate whey to provide a wide variety of products, each having specific and specialized functional characteristics.

There are various miscellaneous methods of processing whey. One consists of spray drying, from a liquid phase, mixtures of whey and skim milk, whey and soy flour, whey and casein and fat, and so on. Another process involves the dry mixing of dry whey and other ingredients to produce products for specific applications. A process which was extremely popular at one time entailed concentrating whey under carefully controlled conditions which, upon cooling, produced a plastic semisolid block of whey. This process is used only on a small scale today. In another application, whey is fermented to produce yeast and ethyl alcohol, with the alcohol being used for the production of spirit vinegar. Roller dryers are still used, but confined to feed products.

Whey Markets Today

Feed markets represent by far the largest outlet for whey products. They are still of great importance and represent excellent volume. Both whole feed-grade whey and partially delactosed whey product are sold in bulk or in bags to the feed industry for incorporation into poultry and animal feeds. Combining whey or whey fractions with soy or casein protein provides the basic ingredients for calf milk replacers for use in veal feeding and herd replacement. Demineralized whey, properly formulated, provides a product, Soweena, used as a milk replacer for baby pigs. Feed-grade whey is also used in dry dog foods and other pet foods.

There is excellent market potential for both edible and feed-grade products. Today, of the total 1.4 billion pounds of whey solids available, approximately 700 million pounds are processed. Some 200 to 300 million pounds of solids are marketed as edible products, while the balance is directed to the feed industry. The industry's major problem is sales.

Many edible plants sell their surplus in feed channels and it is this that creates a serious marketing problem. Whey in feed usage must compete with some very cheap commodities and there is a temptation to look on anything over feed prices as a plus. As a result, edible whey can at times be purchased at less than one-third the price of nonfat milk solids.

The edible markets are intriguing because of the potentially higher margins. However, to supply this market considerable new product and new process development is required, resulting in quite highly sophisticated processing techniques and high investment in capital equipment. Here is where the real marketing of whey products is required.

The market for feed-grade whey products is and will continue to be dominated by whey solids which are processed as a solution to a disposal problem and which will be sold at break-even prices or at a loss if necessary. The only method of competing in this market is to utilize highly efficient and economical processing procedures. In this economic situation marketing is a real challenge, as is the production of these products at a cost which will permit competitive pricing in the marketplace.

Future Products

Sucess in the whey industry will continue to be dependent on the development of markets for improved products of higher value. New products currently becoming available are far more functional than ever before. Instant whey, for example, provides the flowability, dispersibility, and solubility characteristics that have been found so valuable in instantized dry milk solids. High-protein products such as our own High Protein Nutritek provide whey protein in concentrated form and have many applications, both in the food and pharmaceutical fields.

The newer membrane processes, such as reverse osmosis and ultrafiltration, offer excellent potential in whey fractionation as well as the possibility of producing more concentrated whey fractions. Gel filtration is another process which appears to have potential in whey fractionation. Although these processes have technical possibility, the economics are still to be demonstrated, as is the market potential for whey fractions in more concentrated form.

Conclusion

Although cheesemaking is one of man's oldest industries and the whey problem has always been with us, the commercial processing and marketing of whey solids is relatively new. Initially used exclusively for animal feed, whey has now become an important ingredient in the food and pharmaceutical industries. New whey products and new applications for these products will provide additional opportunities in the industry. The economics of the industry will continue to be the primary problem. As the pressure for decreasing stream pollution continues to mount, surplus whey will continue to be processed and marketed at distress prices as a form of waste disposal.

For those of us in the whey-processing business, the only solution is the manufacture and marketing of whey in specialized forms of high value.

Industrial Processing of Whey Today

Like most other aspects of the dairy industry, process and product technology have tended to dominate our thinking. What we need is more markets for our products. Without marketing programs that will develop the margins required to provide funds for the research needed to improve our products, the whey industry will truly be merely a disposal system.

I have great confidence that this will not occur. On the contrary, through new process and product development, the discovery of new product applications, and the use of aggressive and modern methods of marketing, I firmly believe that the whey industry has a sound future.

CONCENTRATION AND FRACTIONATION OF WHEY BY REVERSE OSMOSIS

F. E. McDonough
Eastern Utilization Research and Development Division
Agricultural Research Service, USDA
Washington, D. C.

The problem of whey disposal began with the production of the first commercial cheese. In ancient Rome, it was mentioned by Cato that whey was used for pig feed. Admittedly, the problem could not have been too great then, but as population has increased and as cheese production has increased, so has the whey disposal problem. In a review of whey utilization published in the Journal of Dairy Science in 1948, Drs. Webb and Whittier stated, "More than ever before producers of cheese are seeking new methods of utilizing whey." Today, 22 years later these words have a significantly greater degree of urgency. A major public concern for water cleanliness has led to antipollution legislation which is forcing cheese manufacturers to find an acceptable method of whey disposal. In order for the cheese industry to survive, the disposal methods must be economically feasible.

The problem then is, What do we do with our whey? It has one-half the solids of whole milk, and is rich in amino acids, vitamins, lactose, and soluble protein. Still, it is almost valueless in its raw state. Two major obstacles have prevented greater utilization. (1) Whey contains 93.5 percent water and is highly perishable. Its high bulk and low value make it impractical to transport long distances, either for use as raw whey or for further processing. Therefore it must be concentrated and/or dried for use; but concentrating and drying by existing methods is too expensive for small plants. (2) Almost half of the whey now disposed of is high-acid cottage or baker's type cheese whey. High-acid whey presents special flavor problems, and until recently, could not be adequately dried; thus little effort has been made to find uses for it. The need, then, is for research to develop new uses for whey and new methods for processing whey.

Reverse osmosis (RO) has outstanding potential as a new processing method. A process for separating components of a solution, RO utilizes a semipermeable membrane which allows the solvent (water) to pass through while retaining or restraining other solutes (lactose, salt, and protein). When only water passes, the result is concentration. Membranes can also be made which will allow some select solutes to pass with the water resulting in fractionation. Theoretically, we can remove water and salts from the lactose and protein and even water, salts, and lactose from the protein. Water is forced to pass through in a direction opposite to the flow of normal osmosis. The driving force is hydrostatic pressure in excess of the osmotic pressure of the feed. Reverse osmosis offers lower energy costs than evaporation by freezing or heating, it operates at ambient temperatures, it does not require phase changes, and it promises lower equipment costs.

Presently RO may be used to advantage in three types of food processing applications: concentration, purification or fractionation, and waste disposal. Our first emphasis was on concentration because concentration offers the most help to small-volume plants. It offers them the opportunity to remove 65 to

80 percent of the water with a corresponding decrease in shipping costs. Some processors may be able to use the concentrate in their own plant. As an alternative, they may ship the concentrate to central receiving plants for further processing. Cooperatives may soon be handling all of their whey in such centrally located plants.

Concentration

A report of our efforts on concentration appeared in the February issue of Food Technology, so I will touch only upon the highlights of that work. The membrane, of course, must be supported to withstand pressure. Several types of design are available but we did most of our work on the Havens International tubular type shown in Figure 1. The one-half inch tube is lined with a continuous membrane and the feed liquid is circulated through under pressure. The water passes through the membrane and through the porous walls of the pipe. In a Havens "module," 18 of these tubes, each 8 feet long, are joined by U-tubes inside a single shroud which collects the water. Any number of modules can be joined or used in a parallel series giving great latitude in the size of complete units.

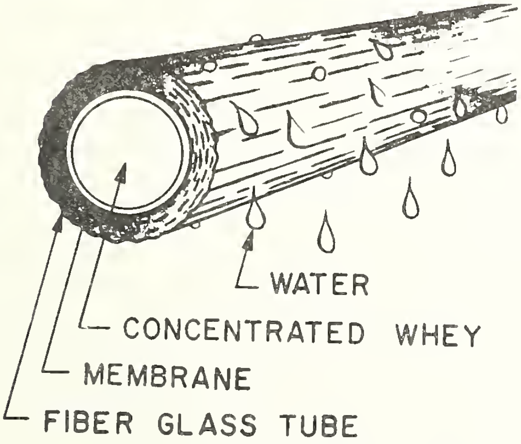

Figure 1.--Diagram of tubular design for reverse osmosis process.

Tables 1 to 4 show the composition of the fractions obtained during concentration of cottage cheese whey using two different membranes. Table 1 shows concentration data using a tight membrane designated Type 5A, with a sodium chloride rejection rate of 95.5 percent. From 680 pounds of whey containing 6 1/2 percent solids, 539 pounds of permeate were removed, leaving 141 pounds of concentrate of 31.4 percent solids--a concentration ratio of 4.8 to 1. As one can see, the data indicate the permeate to be very clean, containing only 0.06 percent total solids. Converting each of these to dry whey as performed in Table 2 reveals more meaningful data. Only 0.72 percent of the total solids are lost with the permeate, leaving over 99 percent of the solids in the concentrate. As would be expected from molecular size, the salts (ash) pass through more easily than other components. Table 3 presents similar data with the same whey using a slightly looser membrane designated Type 3A with a 75 percent sodium chloride rejection rate. The concentration ratio here was almost 5 to 1, from 6.5 to 32.6 percent solids. Although this is considered to be a concentration membrane, some degree of fractionation is evident from Table 4. The smaller molecules are beginning to pass quite readily and almost 24 percent of the salts (ash) were lost in the permeate. Although one may question the amount of nitrogen lost, the loss is just that--nitrogen and not protein. A further analysis shows all of the lost nitrogen to be nonprotein nitrogen (NPN) such as urea, ammonium salts, and amino acids.

TABLE 1.--Solids content of whey fractions before and after RO concentration
(Membrane type 5A:95 percent NaCl rejection)

Fraction	Solids content (percent)		
	Original whey	Concentrate	Permeate
Total solids	6.53	31.40	0.060
Ash	.61	2.88	.017
Lactose	4.39	20.98	.037
Nitrogen	.13	.64	.003

TABLE 2.--Dry weight fractions from RO concentrated whey
(Membrane type 5A: 95 percent NaCl rejection)

Fraction	Total dry weight (lb.) in:			Loss in permeate (percent)
	Whey	Concentrate	Permeate	
Total solids	44.40	44.08	0.32	0.72
Lactose	29.85	29.65	.19	.64
Ash	4.13	4.04	.09	2.22
Nitrogen	.92	.90	.016	1.74

TABLE 3.--Concentration of cottage cheese whey by RO (Membrane type 3A: 75 percent NaCl rejection)

Fraction	Solids content (percent)		
	Original whey	Concentrate	Permeate
Total solids	6.53	32.60	0.30
Ash	.61	2.55	.18
Lactose	4.39	22.20	.07
Nitrogen	.13	.63	.01

TABLE 4.--Dry weight fractions from RO concentrated whey (Membrane type 3A: 75 percent NaCl rejection)

Fraction	Total dry weight (lb) in:			Loss in permeate (percent)
	Whey	Concentrate	Permeate	
Total solids	44.40	42.76	1.64	3.69
Lactose	29.85	29.46	.38	1.28
Ash	4.13	3.15	.98	23.72
Nitrogen	.92	.84	.08	8.69

The next logical question concerns concentration rates. This information is necessary to determine what size unit would be needed for a given volume of whey. Figure 2 shows typical concentration rates of 80- to 100-gallon lots of whey for the 3A and 5A membranes at 600 and 800 pounds per square inch (psi). The greatest difference in rates as affected by both pressure and membrane porosity appeared in the low concentration ranges. Concentration to 15 percent solids with the 3A averaged 0.77 gallon per square foot per hour at 800 psi and 0.51 gallon per square foot per hour at 600 psi--a difference of 0.26 gallon per square foot per hour. The average to 30 percent solids was 0.275 and 0.205 gallon per square foot per hour, respectively, at 800 and 600 psi--a difference of only 0.07 gallon. The slope of these curves leaves an obvious conclusion: the more water removed, the slower the overall rate and thus the higher the cost. In more meaningful terms, one company recently offered, for approximately $20,000, a complete unit containing pump, valves, and all necessary components capable of removing 70 to 75 percent of the water from 3,000 pounds of whey per hour.

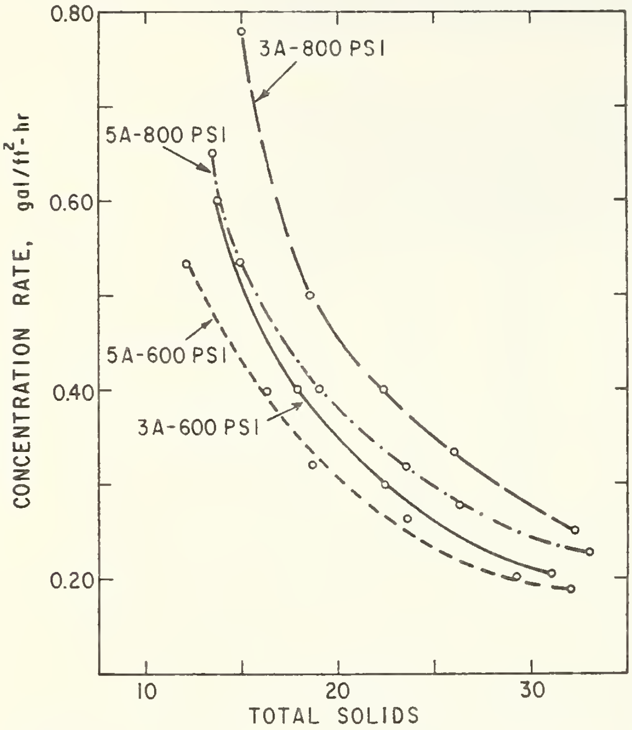

Figure 2.--Influence of membrane type and pressure on average rate of concentration of whey by reverse osmosis.

At this point some problems associated with the process should be reviewed. One of the major obstacles to continuous reliable operation of a concentration system is the decrease in flux rate during operation. Several factors contributing to this drop are as follows:

1. Osmotic pressure
2. Concentration polarization
3. Feed velocity
4. Pressure drop
5. System design
6. Compaction
7. Clogging

We can expect no control over the biggest factor--osmotic pressure. As mentioned earlier, the driving force is pressure. Thus, as the feed is concentrated, the osmotic pressure increases and higher pressures are needed. Since the osmotic pressure of whey is approximately 120 psi, a pressure in excess of that is needed to remove water. The osmotic pressure of 30 percent solids whey is about 700 psi and would have to be exceeded to continue concentration. It is obvious, then, that to concentrate whey to 45 percent solids, high-pressure systems in the area of 1,000 to 1,500 psi will be needed.

The next variable is concentration polarization. As a layer of feed material travels across the membrane, the water adjacent to the membrane surface passes through, resulting in a concentration gradient with layers of uneven concentration. The boundary layer next to the membrane thus has a significantly greater osmotic pressure which soon equals the operating pressure of the system and the flux stops. This phenomenon occurs most during laminar flow and can be controlled to a great degree by feed velocity. Pumping the material through the tubes with sufficient turbulence to overcome boundary layers will minimize the osmotic pressure at the interface.

Pressure drop occurs from friction and is a function of velocity, solids content, and configuration of the tubes. These factors must be considered in the design of a system. Major problems arise when attempting to pump whey through a sufficient number of modules in a continuous flow to concentrate from 6 1/2 to 30 percent solids in a single pass. In addition to pressure drop, as water is removed, the volume of whey becomes less and turbulent flow is soon lost.

A usable system design could be one with the tubes arranged in parallel series with a limit on the number of tubes in the series, thereby limiting the length of continuous flow. This procedure, of course, would require recirculation of the whey and would not be desirable for large operations. A better system would be one with auxiliary pumps in the line to pick up the feed rate. Still another involves "staging" or exiting from a number of parallel series and then flowing immediately into a progressively smaller number of tubes.

Compaction is another limiting factor. The porous substructure of the membrane tends to collapse at high pressure, causing a gradual decrease in permeability over a period of several months. Remedies may result from research on other membrane materials. North Star Research and Development Institute has developed several workable ultrathin membranes that show good promise.

Clogging is self-explanatory. It is minimized by proper turbulence which sweeps the surface clean. In addition, short periods of shut-down to allow flushing with water normally removes accumulated materials and restores flux. We operated twice weekly for one and a half years with no permanent clogging or appreciable loss in permeability.

Fractionation

The second major application for reverse osmosis involves fractionation. Whey powder for human consumption has a much more limited market than animal feed, but there are many potential uses for the product and progress in utilization is being made. There appears to be great marketing potential in breaking down whey into its several components which, sold separately, would bring a better return than the single price of whole whey. Lactose has many important uses. Whey protein, which can be precipitated out of whey by acidifying and heating, is currently sold wet as food for fur-bearing animals. The heat denatures the product, however, and lessens its value as a human food supplement. There is also a good market for desalted whey which is currently produced by electrodialysis. Theoretically membranes can be manufactured to effectively separate each component. Thus far, we have not been able to obtain one which would satisfactorily desalt whey, but we feel it is only a matter of time before such a membrane is developed. Membranes are available for separating proteins from the other components of whey. At this point, many will refer to the process as ultrafiltration rather than reverse osmosis. Typical fractionation results obtained by the Dairy Products Laboratory are shown in Table 5. These results were obtained from 160 gallons of cottage whey, using the Type 215 Havens Membrane at 250 psi and 80°F. Based on percent analysis all data were converted to total pounds of each component. The table shows that most of the solids other than protein readily pass through the membrane. Processing was continued until about 90 percent of the original whey volume was removed as permeate, totaling 145 gallons of permeate and 15 gallons of concentrate. Note that 47 pounds or 79.2 percent of the original weight of lactose was contained in the 90 percent volume of permeate. This means that there was some rejection of lactose by the membrane or we would have had 90 percent of the lactose in the permeate. When calculated in relation to the amount of water removed, we concluded that about 86 percent of the lactose passes through the membrane. We are also losing smaller nonprotein nitrogen (NPN) molecules at the rate of 78.7 percent. While these particular results show no loss of protein, variations have been observed within experimental error and a loss of 0 to 5 percent protein may be expected.

TABLE 5.--Dry weight fractions from RO concentrated cottage whey
(Membrane type: 215 Havens)

Fraction	Total dry weight (lb.) in:			Percent passing through membrane[1]
	Whey	Concentrate	Permeate	
Total solids	98.74	25.04	74.88	82.7
Lactose	59.80	12.30	47.40	86.4
Ash	8.30	1.09	7.26	95.2
Nonprotein nitrogen	.76	.21	.55	78.7
Protein	7.46	7.50	0	0

[1] $\frac{\text{Percent in permeate}}{\text{Percent water removed}} \times 100$

Figures 3 and 4 give an indication of the type of product that can be obtained from these membranes. On a dry weight basis, the original cottage whey contained about 68 percent lactose and about 8 percent protein. The protein content of whey is generally stated as 12 percent, but 4 percent is really NPN. After reducing the volume by 90 percent, the permeate contains a slightly higher ratio of lactose to total solids, but no protein. The

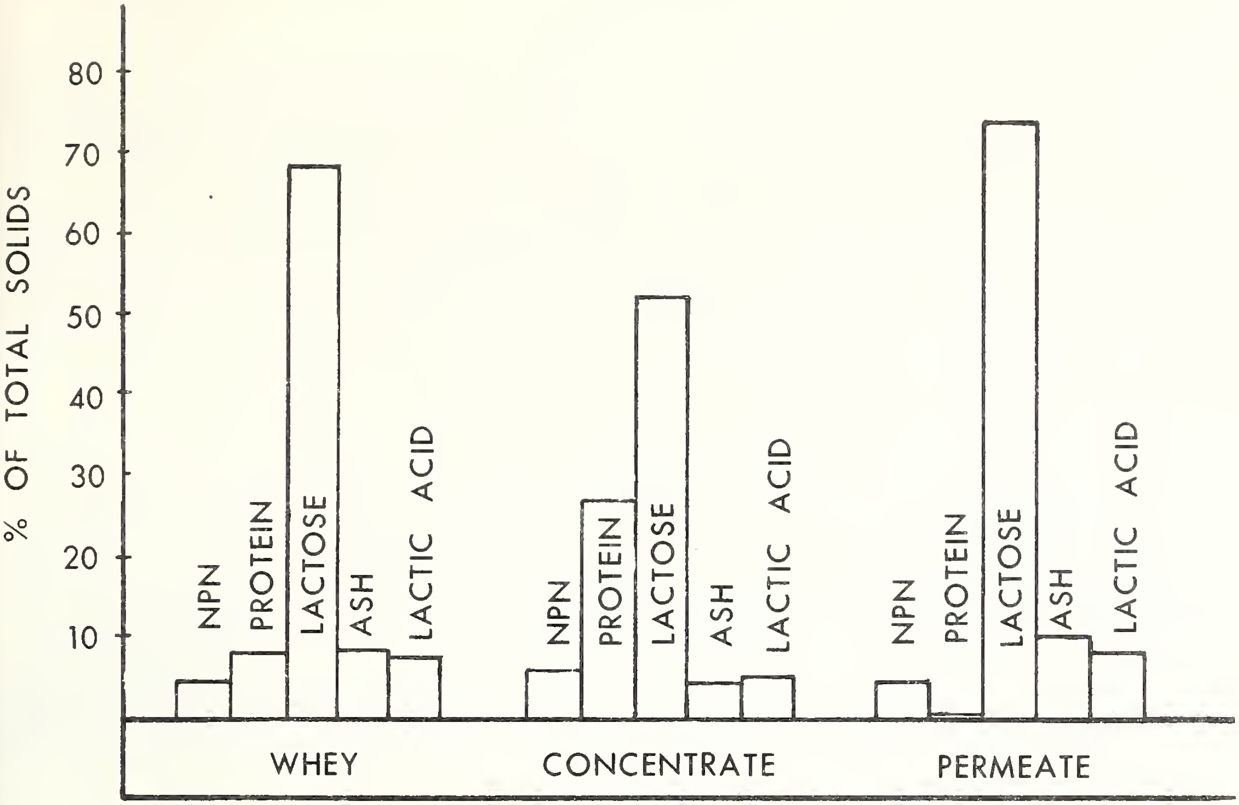

Figure 3.--Fractionation of cottage whey by reverse osmosis.

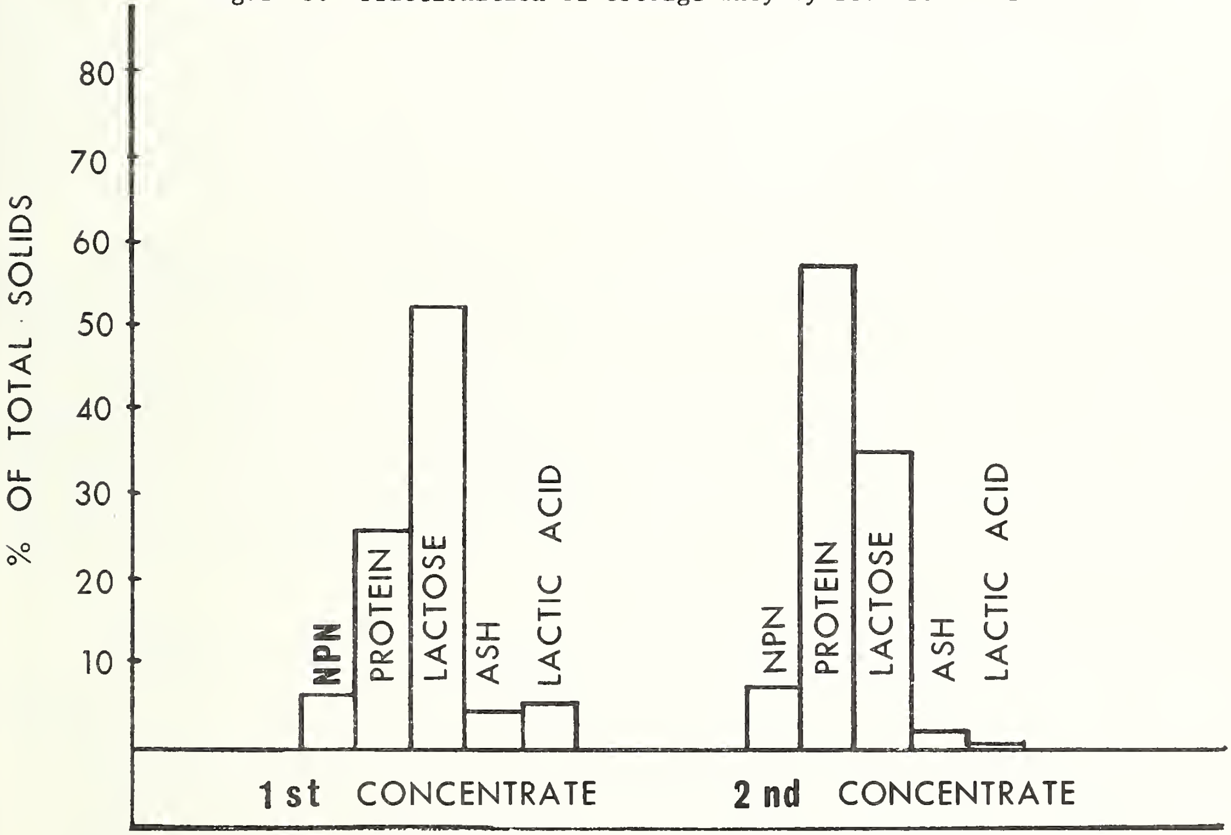

Figure 4.--Secondary fractionation of cottage whey by reverse osmosis.

concentrate is about 20 percent solids and on a dry weight basis contains about 33 percent protein, while lactose has been reduced from 68 to 52 percent. The composition has thus been altered to essentially duplicate that of skim milk. Higher protein ratios can be obtained merely by adding water back to the concentrate and proceeding with a second fractionation as shown in Figure 4. By diluting the concentrate from Figure 3 approximately 9 to 1 with water followed by a second removal of 90 percent of the volume as permeate, we obtained a fraction of about 64 percent protein and 35 percent lactose. An added advantage is the almost complete removal of lactic acid.

The next logical question again involves rates. What volume of whey can one expect to fractionate on a reasonably priced unit? Figure 5 shows the time required to remove various percentages of the original volume. While the rate for removing the first 50 percent is extremely good, we do not believe that degree of fractionation to be adequate. At an 86 percent lactose passage rate, reduction of 50 percent of volume results in a total reduction of lactose of about 43 percent. The minimum goal could be at least an 80 percent reduction of lactose and a 4-fold concentration of protein. To achieve this, one must reduce the original volume by 85 to 90 percent with a Type 215 membrane. This can be done at a rate of about 0.5 to 0.6 gallon per square foot per hour; thus, it appears to be no more expensive than concentration by tighter membranes.

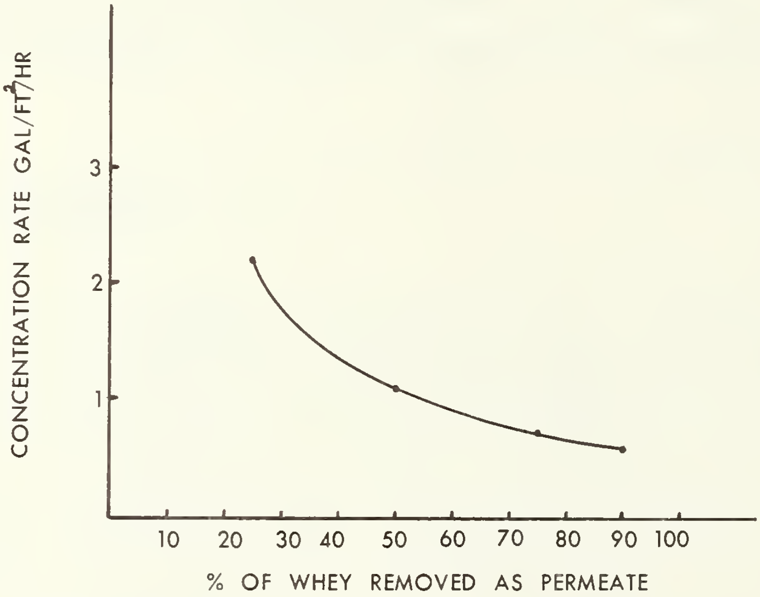

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Figure 5.--Average rates for fractionating whey by reverse osmosis.

Preparation of the 65 percent protein fraction involving a secondary washing fractionation would take almost twice as long, and thus would be more expensive. All the problems associated with concentration also apply to fractionation. In addition, fractionation does not appear to offer a solution for small-volume plants interested in eliminating sewage disposal problems, since the permeate from fractionation could in no way be considered clean enough to dump without further treatment. Larger plants, however, may fractionate and then recover the lactose from the permeate or dry the permeate for animal feed.

Fractionation into a high-protein product offers the possibility of upgrading the use of whey, and thus the burden of whey disposal may become an opportunity. Our research and that of others lend optimism to the long-range prospects for whey utilization, although significant developments are a few years off. We feel that concentration and fractionation by reverse osmosis will play a large part in determining how fast this utilization will occur.

Discussion

QUESTION: Can you give us some information on the BOD content of the fractions after the first and second step?

MR. McDONOUGH: We haven't actually determined any BOD's, unfortunately, but based on our knowledge of the material going through, and of what contributes the most to BOD, the fact that we get 99 percent of the solids in the concentrate would indicate that we are pretty sure of reducing the BOD by at least 99 percent. I believe Abcor had some data. Bernie Horton, do you have any data on the BOD level of that material?

MR. HORTON: Under the FWQA program, we are evaluating a series of RO modules and membranes, and we obtain a reduction in BOD of about 99 percent. We have a very good situation as far as the BOD of sweet whey is concerned. In the case of acid whey, of course, there is a problem with the lactic acid. We can neutralize that, but we are still faced with the local problem that we cannot discharge to the sewer anything containing more than 20 parts per million organic matter. We are about to deliver a pilot plant that will be run daily so we can get the information we need on a fairly decent scale.

QUESTION: You said that the flux rate in fractionation is no slower than in concentration. Should it not be considerably greater since the osmotic pressure is not so much a hindrance?

MR. McDONOUGH: You're right if you use the same pressure, but the fractionation membranes, being more porous, have a greater limit on the working pressure that you can use. I know that with the Havens fractionation membranes, 400 psi is the absolute maximum, where we used 600 to 800 in concentration. I believe the Abcor membranes use about 50 psi. Since osmotic pressure is not so much a factor, you can use lower pressures. By doing so your flux rates aren't that much different.

QUESTION: Have you done any work on the rate of shear? Does the rate of shear of the liquid flowing at turbulence denature the protein? There is evidence that electrophoresis patterns are unchanged, indicating there is not denaturation through shear.

DR. HOOVER: In general, proteins are not denatured through shear unless there is air present in the system.

QUESTION: Could you give an estimate of the life expectancy of membranes?

MR. McDONOUGH: Some have been in operation 4 or 5 years with sea water. It depends on the product and the composition of the product. The estimates that we have received are that they should last at least two years with whey. Now we used some membranes for two years, operating about twice a week, and although a number of the units failed, the membranes were fine; the problems were in the U tubes where they lost elasticity, and I understand those problems have been corrected. So it should be at least two years.

QUESTION: Would it be feasible to purify the protein by fermentation after it is separated to get the balance of the lactose out?

MR. McDONOUGH: Yes, but then you would have to separate the fermentation products again, right?

QUESTION: The lactic acid wouldn't be hard to get out, but what would this do to the protein?

DR. HOOVER: It would probably affect it very little if *fragilis* is used, since it is completely nonproteolytic.

QUESTION: How do you clean the units?

MR. McDONOUGH: That's one of the comments I thought would come out so I didn't mention it. Sanitation of the unit is a major problem, and we have been working on it just about full time for about two months now. We are scheduled to give a paper on sanitation at the American Dairy Science meeting at the end of this month. We have some good leads, but we have to tie up some loose ends. We have found a number of chemical materials that will give a certain amount of control. These are acceptable to the Food and Drug Administration and are already on the Generally Regarded As Safe list. The question is, What type of control are you looking for? We originally estimated that around 99.9 percent kill would be great. But if you have 10^6 coliforms, that would only bring it down to 10^4, and that's not good enough. And then it also depends on whether you want to operate the unit on a 20-hour day and allow 4 hours for sanitation, or if you are going to shut down for 10 hours. Our goal right now is to sterilize in 4 hours. We have done this, but the materials we used are expensive. We can get 99.99 percent kill very easily. Basically organic acids, such as acetic acid, will certainly prevent the growth of bacteria. They won't take care of yeast and molds, though. We have some other compounds, like hexylresorcinol which is deadly on yeast, but costs $5 for 25 grams. In the next 2 or 3 weeks we expect to get a little more information which we will give out at the American Dairy Science meeting.

QUESTION: In your evaluation of the degradation of these membranes, you mentioned compaction. In reverse osmosis do you feel it is true compaction or is it the deposition of another proteinaceous layer on the membrane that is responsible for this?

MR. McDONOUGH: In our work with the membranes we had no loss of permeability. Generally at the end of each run under standard conditions we determined the flow rate of water and used that as a standard. At the end of the year and a half, running two days a week, we did not get any change in type 5A, which is the tightest, or in type 4A, which is an intermediate. We lost about 5 percent in flow rates on the 3A, which is the one that allowed about 24 percent of the salts to go through. To determine whether or not we had compaction, we tore the membrane apart and just examined the surface of the material under a scope or tried to scrape material off. It's pretty hard to tell what it's due to. But we feel it was compaction.

QUESTION: Did you have considerable osmotic pressure at the higher concentration after the salts went through?

MR. McDONOUGH: We did not notice much difference since we removed only 24 percent of the salts. If we had removed 100 percent, the osmotic pressure of the concentrate would have been lower.

COMMENT (Mr. Guy, Aqua-Chem, Inc.): You have probably made the same observation as we have in using conductivity cells, that as the concentration proceeds, the conductivity is about the same on both sides of the membrane, concentrate and permeate.

MR. McDONOUGH: This is about what we observed, too.

QUESTION: Can we see some of this concentrate during the demonstration?

MR. McDONOUGH: Tomorrow we will demonstrate the unit, and we will run whey through the fractionation membrane just to give you an idea of what the permeate looks like. Naturally, with the solids in it, it will not look as clean as water. I don't think we will be able to run it long enough to actually concentrate to a great extent, but I can show you some powder that we dried from the concentrate.

QUESTION: Do you monitor the program to determine the utility of the protein fraction?

MR. McDONOUGH: In Dr. Webb's estimation, that's probably the next most important piece of work we should do. Right now we do not have the personnel to do all that. Dr. Hargrove is working to find new uses for this product. We have been so tied up with sanitation work that I haven't been giving him enough concentrate to get much done on that aspect.

QUESTION: Have you done work with reverse osmosis on demineralized whey to determine what concentrations are feasible?

MR. McDONOUGH: No. The companies have not been able to provide a satisfactory and reproducible membrane that will allow most of the salts to pass through.

QUESTION: Have you tried electrodialysis ahead of the membrane?

MR. McDONOUGH: No, we have not done that.

WHEY FERMENTATION

B. M. Mayer
Knudsen Corporation
Los Angeles, Calif.

One of the tools available to us in our efforts to utilize whey is the manufacture of useful products through the growth of microorganisms. There are many microorganisms that ferment whey, and many metabolic products that are formed as they grow. The trick is to find microorganisms and processes which will produce products of sufficient value to be commercially interesting.

The use of fermentation is not a unique approach. An entire industry is based upon it, which can be divided into (19):

1. The alcoholic beverage division.
2. The pharmaceutical division, which includes antibiotics and steroids.
3. The food supplement division, which includes amino acids, vitamins, yeast, and algae.

Where does whey fit into this scheme? It hasn't made the grade yet in alcoholic beverage production, but it has been used in the manufacture of certain antibiotics, organic acids, vitamins, and yeast. Because of its high milk sugar content, whey is primarily of value as an energy source, though it is conceivable that some other component might be attractive as well.

The fermentation industry is characterized by a certain degree of flexibility with respect to raw materials (23). And since this is a highly competitive industry which must operate with maximum production efficiency, the substrate which will produce the end product at the lowest cost will be the one that is used. If a fermentation process can use whey, and it provides a cheaper source of energy than other raw materials which would be suitable, it will probably be used.

As an example of the use of whey by the fermentation industry, let us briefly consider penicillin production. During the early phase of its development, lactose appeared to be required for high yields. The reason lactose worked so well was that it is used at a slower rate by the penicillin-producing molds than were other carbohydrates. This resulted in better pH control, good growth rates,and higher penicillin yields. Later it was discovered that, by controlling the rate of availability of other more readily utilized energy sources, lactose was not required.

But if lactose was used for penicillin production, why wouldn't whey do just as well? Its solids are 70 percent lactose and would be a considerably cheaper source of lactose in this unrefined state.

The answer is that foaming is very difficult to control in a whey medium, and enrichment and purification procedures become unduly involved (13).

The use of whey in the manufacture of vitamin B_{12}, riboflavin, lactic acid, and ethyl alcohol has also been tried, but whey is not the cheapest energy source for these fermentations. However, this does not rule out opportunities for whey fermentation processes. It simply means that we must confine our activities to products in which the use of whey will assume an advantageous position with respect to other energy sources.

Whey is a food ingredient with many of the desirable properties of milk. Its use in fermentation should be in areas where we can utilize these properties to advantage. One such process is the production of yeast.

The process is relatively simple. Live yeast is added to whey either in the form of fermented whey or yeast cream, and suitable growth conditions are established. Nitrogen must be supplied, pH and temperature controlled, and lots of air injected. As the yeast grows, the lactose is consumed and when the lactose is gone, the fermentation is complete. The yeast is then harvested and dried.

The selection of the best yeast for this fermentation has been considered by a number of workers. The primary requirement, of course, is the ability to use lactose. The production of yeast on other substrates, such as molasses and sulfite liquor, employs Saccharomyces cerevisiae or Torula utilis, but neither of these is capable of using lactose. Saccharomyces fragilis, on the other hand, can use lactose, and this is the yeast used by Wasserman and his coworkers (24-31) in their thorough study of the yeast fermentation of whey. Amundson and his associates (1-4, 22) at the University of Wisconsin also studied this same fermentation more recently. Other lactose-fermenting yeasts have been used by other workers, but the discussion here will be based on the works of Wasserman and Amundson and their coworkers.

Wasserman, Hopkins, and Porges (31) found that Saccharomyces fragilis uses lactose without hydrolysis to glucose and galactose, though it is capable of using these sugars. In addition, lactic acid that has developed in the whey is used very rapidly by the yeast and disappears in the early phases of growth. This is very desirable, as wheys from different processes contain different amounts of lactic acid. Sweet whey from Cheddar and Swiss cheese manufacture contains about 0.2 percent lactic acid, whereas whey from lactic casein manufacture contains about 0.6 percent.

An important reason for using Saccharomyces fragilis for the production of yeast from whey in the United States is that the FDA has approved its use as a food yeast (11).

In addition to lactose and lactic acid, some of the nitrogen-containing compounds present in whey are available to the yeast as nitrogen sources. Wasserman (27) found that yeast uses about 50 percent of the ammonia nitrogen fraction of the whey and about half of the soluble organic nitrogen which is composed of proteose peptones, amino acids, and other substances. However, lactalbumin and lactoglobulin, the heat- and acid-precipitable whey proteins, cannot be used.

The nitrogen that is available from the whey is not nearly adequate for the amount of yeast that can be formed from the carbohydrates it contains.

Consequently, nitrogen must be added so that the growth of the yeast and its composition will not be limited. Wasserman (25) found that Saccharomyces fragilis growing alone in whey had a nitrogen content of 4.9 percent, but when 1 percent ammonium sulfate was added, cells contained as much as 8.2 percent nitrogen. This variation occurs in yeast despite the fact that its amino acid composition and concentration in the protein of the yeast cell remain constant. The differences are in the amino acids present in the extractable fraction of the yeast.

In addition to nitrogen, Wasserman (25) found that he obtained greater yields by adding phosphorus at the rate of 0.22 percent. When mono- or di-ammonium phosphate was used, the additive served as a buffer, as well as a source of nitrogen and phosphate.

Wasserman, Hopkins, and Porges (31) found that when 0.1 percent yeast extract was added to the whey, it increased the cell count, net dry weight, and sugar utilization. Amundson (2) used 0.3 percent yeast extract or 1 percent corn steep liquor. Others have suggested the addition of byproducts from the manufacture of glutamic acid and sodium glutamate.

Oxygen, usually supplied in the form of air, is the remaining nutrient required by the yeast. In the absence of air, yeast converts sugar to alcohol. In the presence of air, sugar is converted into yeast cells. This is the Pasteur effect, simply expressed, and describes the importance of adequate aeration for the best growth.

Yeast production requires larger amounts of oxygen than other microbiological processes. Chapman (10) reports that as much as 6,000 cubic feet of air per minute may be used in a 10,000-gallon culture of bakers' yeast.

The problem of supplying yeast with an optimal quantity of available oxygen throughout its growth period has not been easily solved, and there have been many patents issued on fermentor designs for improving the aeration of yeast fermentations.

The device most commonly used in the manufacture of bakers' yeast is an arrangement of perforated pipes in the bottom of the vat. This method is inefficient and requires large volumes of air, but it is cheap and reliable.

The type of fermentor developed for antibiotic production employs an impeller rotating at a fairly high speed near the bottom of the tank. With the aid of baffles on the sides of the tank, this breaks a rising air stream into fine bubbles and mixes them with the liquid for longer retention.

Another fermentor which has been used in yeast production is the Waldhof fermentor which uses a turbine-type agitator and a draft tube.

Hand in hand with the problem of supplying available oxygen to the yeast is the problem of foam control. Whenever air is bubbled through whey, a heavy foam is produced and a real problem is created for the processor. In this respect whey is certainly one of the more difficult materials to ferment industrially.

The temperature of the fermentation should be about 86° F. This means that cooling must be provided as the growing cell liberates a large amount of heat. If the temperature rises too high, the cells will be damaged and growth will slow down. Wasserman (25) found that the yeast grows at 105° F., but he was troubled with contamination at this higher temperature.

The pH of the fermentation should be kept at 5.0 to 5.7, according to Wasserman (31) who found that when 0.5 percent ammonium sulfate and 0.5 percent dibasic potassium phosphate were added, stabilization occurred at pH 5.7 and subsequent maintenance was not a problem. Amundson (2), however, prefers to maintain a pH of 3.5. There are other aspects of pH control which must be considered in addition to optimum yeast growth. At a low pH, corrosion can be a problem, whereas contamination and increased foam stability result from a high pH.

Following the fermentation the yeast must be harvested. This is accomplished by means of a yeast separator or self-cleaning clarifier which produces a cream of between 15 and 30 percent solids. This may be spray dried or roller dried, depending upon the facilities available.

The yield of yeast varies with the efficiency of the fermentation, with oxygen the most likely limiting factor. Amundson[1/] calculates that 0.55 pound of cells can be obtained from a pound of lactose. Wasserman, Hopkins, and Porges (31) state that 27 mg. of yeast should be obtained from 1 ml. of whey, but they obtained only 23 mg. of yeast, or 85 percent of the theoretical yield.

One of the advantages of yeast fermentation is the reduction of waste that can be accomplished. Regrettably, this is not 100 percent. Amundson (2) reduced the COD, or chemical oxygen demand, from 65,000 to 10,000 p.p.m. Wasserman obtained similar results. The final COD, however, varies with the efficiency of aeration, just as does the yield of yeast.

The costs of producing yeast were estimated to be about $0.076 a pound, according to Wasserman, Hampson, and Alvare (28), in 1961. Muller estimates a cost of $.20 a pound, on a 100 percent protein basis. Different values can be obtained, of course, depending on whether the whey is considered to have a positive or negative value or no value at all.

Wasserman (24) found that the amino acid composition of the protein of Saccharomyces fragilis grown in whey was somewhat higher than that of yeast grown on other media, particularly the lysine.

Muller (16) found that the protein value of whey-grown yeast was increased by the addition of whey protein, raising the score from 65 to 87 when compared with the FAO provisional amino acid pattern, based on Amundson's analyses. The sulfur-containing amino acids contributed by the whey protein were largely responsible for the improved score. Wasserman (24) found the vitamin B composition of Saccharomyces fragilis to be within the ranges reported for other microorganisms. The vitamin content varies with the yeast strain, medium composition, and cultural conditioning. Since whey contains little

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[1/] Unpublished data.

thiamine, the yeast grown on it is also low in thiamine. This value can be increased by thiamine fortification of the whey, if desired.

Yeast containing whey proteins has been incorporated into the diets of different animals and has proven to be an excellent source of proteins and vitamins. Booth, Robbins, and Wasserman (6) fed a yeast-whey protein preparation to rats and observed improved growth when diets contained as much as 20 percent of the additive.

Metwally, Amundson, Garver, and Shackelford (14) found that mink receiving a washed yeast-whey product attained their maximum weight one month earlier than did animals on a control diet; the fur was equal in quality. The unwashed product was unsatisfactory for optimum growth and survival of the mink.

There have been a few commercial processes involving the fermentation of whey by yeast. One of these is the French SAV process which was recently described by Muller (16) and is being used commercially in France and Russia. In this process, whey is supplied to two vigorously aerated continuous fermentors in parallel. The fermentors differ in size, but process similar amounts of whey. In the larger fermentor, with a longer residence time, the sugar is completely consumed, whereas in the smaller fermentor, only a partial fermentation is obtained. The products of the two fermentors are combined, condensed to about 30 percent solids, and spray dried. The yeast used in the process is *Torula cremoris*. This process results in a modified whey product with an improved protein/lactose ratio but with a high ash content.

Another French process is that of the Fromageries BEL (5). In this process the whey is acidified and denatured by heat as soon as it comes from the cheese plant and the protein is recovered by a decantation filtration. The deproteinated whey is then fermented with *Saccharomyces fragilis* and *Saccharomyces lactis*. The fermented whey is centrifuged to 10-12 percent dry matter, filtered, plasmolyzed, and dried. Five tons of yeast and one ton of whey protein are produced from 65,000 gallons of whey per day by this process.

A Czechoslovakian process employs *Torula* and *Torulopsis* strains of yeast and three fermentors of about 5,250-gallon capacity, each of which is capable of processing over 13,000 gallons of whey per day. The fermentors are equipped with power-driven "suction" turbines carried on hollow open-top spindles with holes just above the whey level which suck foam continuously into the turbine. The fermentation takes about 8 hours at 30° C. and yields 51-54 percent solids in relation to the lactose fermented.

In the United States, Stimpson and Young (21) of Kraftco have patented different aspects of a process closely related to those of Wasserman and Amundson. In this patent, the fermented product is heated to release the cell constituents and is then condensed or condensed and dried for use in feedstuffs.

In our company, the Knudsen Corporation, cottage cheese whey is utilized by fermenting with *Saccharomyces fragilis*. Two products are made, one being a straight dried yeast and the other we call Wheast, a blend of yeast and whey proteins.

Large quantities of cottage cheese are made by Knudsen and sizeable quantities of whey must be disposed of. Our principal cottage cheese factory is located in the City of Visalia, about 200 miles north of Los Angeles. As a result of our cheese production, we have about 50,000 gallons of whey a day, 7 days a week. The City of Visalia with a population of 25,000 people is not prepared to dispose of this volume of whey in its municipal sewage plant, and we have had to find other means of disposal.

We began producing yeast in 1961, and have operated almost continuously ever since. As a result of this process, we have achieved a considerable reduction in BOD.

The yeast plant is situated in the northeast corner of the building complex of our Visalia plant. It is separated from the creamery proper by a row of buildings housing the boilers, sales and general offices, and maintenance shops.

We were worried during the early days of operation that the yeast might contaminate the cottage cheese and other products manufactured in Visalia, but this has never been demonstrated to be a problem.

To prepare whey on which to grow yeast we must first make cheese. The incoming milk is separated into cream and skim, and the latter is pasteurized and pumped into one of twelve 35,000-gallon cheese vats. Here cheese starter is added and acidity is developed. At the proper time, the coagulated milk, which is in the form of a soft gel, is cut into cubes with stainless steel wire cheese knives. The curd is slowly heated and gently agitated until the whey has been expressed from the curd and the texture of the cheese is considered right by the cheesemaker. At this time the pH of the whey is about 4.5 and the temperature is at least 130° F. These conditions are detrimental to most bacteria and prevent growth of Salmonellae.

The agitation is stopped when the curd has been adequately cooked and allowed to settle to the bottom of the vat. The whey is then pumped out of the vat through a sieve which holds back the cheese curd, and is directed to the yeast plant for further processing.

The drained cheese curd is washed with tapwater then a mixture of tap and ice water, and finally ice water. It is then dispensed in 12-gallon cheese cans for later packaging in Visalia or Los Angeles.

The cheese wash water is passed through a centrifugal curd concentrator to remove the cheese fines and then pumped to the yeast plant where it is used for cooling.

The whey is first accumulated in storage tanks at the yeast plant, then steam-injected to a temperature of 200° F. to precipitate the whey proteins, and then cooled to 90° F. through a heat exchanger for fermentation.

When a sufficient volume of the temperature-adjusted whey has been accumulated, it is pumped into the fermentor and inoculated with yeast cream. Oxygen (in the form of air), nitrogen (in the form of ammonia), and sulfuric acid (to maintain a pH of 5) are supplied throughout the fermentation and cooling is provided to neutralize the heat generated in the fermentation process.

The fermentation process takes about six hours, and is continued until all of the sugar has been utilized and growth has essentially stopped. At this time the fermented whey is pumped to holding tanks for subsequent processing.

The next step is to harvest the yeast. A continuous yeast separator is used to spin the yeast cells and milk proteins out of the whey in the form of a cream, which is subsequently dried. The effluent stream is discarded.

The cream, which is dried as it comes from the separator, is called Wheast and is sold as a feed product. It contains yeast cells and whey protein.

If the cream is washed by diluting with water and reseparated to remove the salts and then dried, food-grade Wheast is produced.

If the whey proteins are not heat denatured, they remain in a soluble form and are discarded in the effluent. In this case, the cream is composed of yeast cells only. They are diluted with water and reseparated and dried. This product is sold as Fragilis Yeast.

Our yeast products are dried on roller driers. One of the problems we have encountered with this process is that of obtaining consistently good drying, particularly of the feed-grade material.

Another problem we have encountered is that the vapors from the fermentors and roller driers are objectionable to the local residents, so we have taken steps to reduce the odors by washing the exhaust air stream in a scrubber before it is vented into the atmosphere.

While we are on the subject of problems, another one that we face is that of BOD, or biological oxygen demand. The original whey has a BOD of 30,000 p.p.m. After fermentation, the BOD of the separator effluent stream is reduced to between 3,000 and 6,000 p.p.m. and the total volume of whey to be discarded has been reduced from 50,000 to about 35,000 gallons per day of waste. But this is still a sizeable amount of BOD! We are currently studying methods for the further reduction of this waste-stream BOD.

The primary outlet for our fermentation products has been for the feeding of animals where they serve as a protein supplement with high levels of B vitamins, but they seem to have other valuable attributes as well.

Wheast is used extensively in the feeding of poultry, particularly turkeys, which have a very high protein requirement when they are young. Because of its high protein value, Wheast serves as a supplement in trout and mink feeds, both of which require high levels of protein.

Wheast has found a place in pet foods and considerable quantities are sold for use in dry as well as canned varieties.

Dr. Kenneth Hagen (12) in the April 1970 issue of National Geographic mentions that when Wheast is mixed with sugar and water it is an excellent food for green lacewings and hover flies which are predatory insects used in biological control work. Beekeepers are also finding that their bees are aided by Wheast in their winter feeding.

Wheast and whey mixtures form the basis for very successful milk replacers for dairy calves. Wheast has proven very stimulatory to dairy cattle in the treatment of certain rumen disorders and is being tried, with interesting results, as an ingredient in lactating dairy cow rations.

Over 90 percent of our whey fermentation products are sold for animal feeding at this time. Because of the very low cost of various vegetable proteins in feed rations, it is a constant struggle to maintain an interest in our product at $.11 to $.12 a pound. And at this price, the process is little better than marginal.

The proper place for our products is in human foods where there is a better opportunity to obtain a more realistic profit margin.

Fragilis Yeast has found a place in human foods where it replaces other food yeast in formulations without label changes. It has found a place in health foods and baked goods and as a flavor base. The light color and bland, toasted-nut flavor of the yeast add to its ever-increasing applications in foods.

The product which we are most pleased with is Food Wheast. At a 58-60 percent protein value, it compares favorably with most protein supplements, not only in total protein, but in amino acid composition and protein efficiency ratio as well. We believe that it has great potential as a food supplement.

One Food Wheast product, which has been made in our laboratory but has not reached the market, is a very tasty snack product which contains 18 percent protein, or better than the equivalent of a hot dog in protein content.

We are convinced, after several years of experience with Wheast, that it has real value as a food supplement. There are many people in our organization who take Wheast on a daily basis, and they claim that it gives them energy and causes the remission of arthritis symptoms. We have not attempted to explore these claims.

Bundus and Luksas (7-9), of Beatrice Foods, patented a process in 1969 for the production of bread flavor by the growth of yeast in cottage cheese whey. I am fascinated by their patents because they represent a food application for yeast-fermented whey, not as a food *per se*, but as a flavor accentuator.

According to Peppler (18), yeast has long been used as a protein flavor enhancer. Viable yeast is self-digested under controlled conditions to yield soluble fractions rich in amino acids and other flavorful compounds. Acid-hydrolyzed yeast, resulting from the addition of water and acid to dried yeast followed by digestion, is also used. Yeast from whey could be used for this purpose as well as yeast from other sources, and perhaps the addition of whey proteins might make these products of even greater interest.

Lactose is hydrolyzed to glucose and galactose by lactase, or beta galactosidase, which is found in lactose-fermenting yeast, molds, and bacteria, in the intestinal wall of various animals. Kraftco scientists (15, 17, 20) pioneered in the research on lactase, and their processes involve procedures somewhat similar to those already described, since Saccharomyces fragilis growing on whey is used to produce the lactase.

Lactase is an example of a fermentation product which can be used to modify foods to make them more desirable.

The opportunity for fermentation in the utilization of whey has never been greater. Through the use of yeast, we have a simple and reliable means of converting sugar to protein and turning an unbalanced food into a well-balanced one. Yeast fermentation can be used alone or with other processes for whey utilization. It can be the primary process in whey treatment or a scavenger to utilize the leftover fragments.

Our thoughts with respect to the fermentation of whey should not be confined to yeast, however, Other fermentations which serve to modify whey so as to enhance its value as a foodstuff should be considered. Our biggest problem in the fermentation of whey is our lack of resourcefulness. Perhaps this is due to the magnitude of the problem. The path to new whey fermentation processes which are industrially successful will require some ingenuity.

Discussion

DR. HOOVER: I gathered several years ago that there was a very real, but not very well explained, increase in the hatchability of turkey eggs, and that this was one of the things that gave your feed Wheast a big push in the early days. You spoke about its being used for turkeys and for the rapid growth of poults. Has the hatchability effect been established?

MR. MAYER: I don't really think we have any more information on this now than we did then. We haven't really done too much in the way of controlled experimentation on this product.

QUESTION: In your fermentations, don't you get some alcohol in what we call the beer? With bakers' yeast, we end up with about 5 percent alcohol at the most in the beer. We add molasses continuously. At no time did we really find any sugar. Would this also be true for whey?

MR. MAYER: Very possibly so. Is this continuous fermentation?

QUESTION: Batch fermentation, but continuously adding the feed.

MR. MAYER: Of course, this is easier with molasses at 50 percent concentration of sugars than with whey where the solids concentration is only about 5 percent. You have to use a continuous fermentation of some sort for such dilute substances. Continuous fermentation is good, but it's a little more involved to set up. We like a simple process, at least at this time.

QUESTION: What is the approximate composition of your effluent from the process?

MR. MAYER: It doesn't contain any sugar. Depending on the efficiency of separation it will contain a few yeast cells and a little whey protein that slip by the separator. There are some nitrogen fractions from the whey, a certain amount of intermediate metabolic products, such as ethyl acetate and ethyl alcohol, partial breakdown products of the lactose, and salts from the fermentation process and from the whey.

QUESTION: Do you attribute the nutlike flavor to the roller dryer, and how does that compare to the cream that comes from the separator?

MR. MAYER: Flavorwise, there is no comparison. The flavor of the cream is quite yeasty. I think the roller drying has a definite heat-toasting effect.

QUESTION: What type agitation do you use?

MR. MAYER: We use simple bakers' yeast type with an aeration sparger.

QUESTION: What do you do with the effluent?

MR. MAYER: Discard it. We are now working on a better system of handling the effluent.

QUESTION: Are other companies making these products?

MR. MAYER: Kraft makes some, and according to Dr. Amundson, there is a plant in Wisconsin that is making them in a large pilot plant. That's all that I know of in this country.

Literature Cited

(1) Amundson, C. H.

1967. Increasing the protein content of whey. Amer. Dairy Review 29 (7): 22, 23, 96-99.

(2) Amundson, C. H.

1967. A 1967 solution for Italian cheese whey disposal increasing the protein content of whey. Fourth Annual Marschall Invitational Italian Cheese Seminar, Madison, Wis.

(3) Amundson, C. H.

1966. Whey utilization. Proc. 33rd Washington State University Institute of Dairying, pp. 41-52.

(4) Amundson, C. H.

1966. Increasing the protein content of whey through fermentation. Proc. 33rd Washington State University Institute of Dairying, pp. 23-30.

(5) Blanchet and Biju-Duval.

1969. Whey yeast; methods used at Fromageries BEL, in France. International Dairy Federation Seminar on Whey Processing and Utilization held at Freising - Weihenstephan, Germany.

(6) Booth, A. N., Robbins, D. J., and Wasserman, A. E.

1962. Whey yeast rat-feeding study. J. Dairy Sci. 45: 1106-1107.

(7) Bundus, R. H., and Luksas, A. J.

1969. Bread flavor. U.S. Patent No. 3,466,174. Sept. 9.

(8) Bundus, R. H., and Luksas, A. J.

1969. Manufacture of synthetic bread flavor. U.S. Patent No. 3,466,176. Sept. 9.

(9) Bundus, R. H., and Luksas, A. J.

1969. Bread flavor concentrate. U.S. Patent No. 3,466,171. Sept. 9.

(10) Chapman, L. P. J.

1966. Food yeast from whey. New Zealand Jour. Dairy Tech. 1 (3): 78-81.

(11) Federal Register

1963. Vol. 28, No. 97, 4948.

(12) Hagen, Kenneth S.

1970. Following the ladybug home. National Geographic 137 (April): 543-553.

(13) Leviton, A., and Marth, E. H.

1965. Fermentation. In Fundamentals of Dairy Chemistry, B. H. Webb and A. H. Johnson, eds. Avi Publishing Co., Westport, Conn.

(14) Metwally, M. E., Amundson, C. H., Garver, J. C., and Shackleford, R. M.

1964. Preparation and utilization of a protein-enriched food supplement from fermented whey. J. Dairy Sci. 47: 680.

(15) Morgan, E. R.

1955. Lactase enzyme preparation. U.S. Patent No. 2,715,601. Aug. 16.

(16) Muller, L. L.

1969. Yeast products from whey. Process Biochemistry. Jan. pp. 21-23,26.

(17) Myers, R. P., and Stimpson, E. G.

1956. Production of lactase. U.S. Patent No. 2,762,749. Sept. 11.

(18) Peppler, H. J.

1967. Yeast technology. In Microbial Technology, H. J. Peppler, ed. Reinhold Publishing Co., New York, N. Y.

(19) Rose, A. H.

1961. Industrial microbiology. Butterworth, Inc., Washington, D. C.

(20) Stimpson, E. G.

1954. Conversion of lactose to glucose and galactose. U.S. Patent No. 2,681,858. June 22.

(21) Stimpson, E. G., and Young, H.

1957. Increasing the protein content of milk products. U.S. Patent No. 2,809,113. Oct. 8.

(22) Stuiber, D. A.

1966. Whey fermentation by Saccharomyces fragilis. M.S. Thesis, University of Wisconsin, Madison, Wis.

(23) Underkofler, L. A., and Hickey, R. J.

1954. Industrial fermentations. Chemical Publishing Co., New York, N. Y.

(24) Wasserman, A. E.

1961. Amino acid and vitamin composition of Saccharomyces fragilis grown in whey. J. Dairy Sci. 44: 379-386.

(25) Wasserman, A. E.

1960. The rapid conversion of whey to yeast. Dairy Engin. 77: 374-379.

(26) Wasserman, A. E.

1960. Whey utilization. II. Oxygen requirements of Saccharomyces fragilis growing in whey medium. Appl. Microbiol. 8: 291-293.

(27) Wasserman, A. E.

1960. Whey utilization. IV. Availability of whey nitrogen for the growth of Saccharomyces fragilis. J. Dairy Sci. 43: 1231-1234.

(28) Wasserman, A. E., Hampson, J. W., Alvare, N. F., and Alvare, N. J.

1961. Whey utilization. V. Growth of _Saccharomyces fragilis_ in whey in a pilot plant. J. Dairy Sci. 44: 387-392.

(29) Wasserman, A. E., and Hampson, J. W.

1960. Whey utilization. III. Oxygen absorption rates and the growth of _Saccharomyces fragilis_ in several propagators. Appl. Microbiol. 8: 293-297.

(30) Wasserman, A. E., Hopkins, W. J., and Porges, N.

1959. Rapid conversion of whey to yeast. Internatl. Dairy Cong. 2: 1241-1247.

(31) Wasserman, A. E., Hopkins, W. J., and Porges, N.

1958. Whey utilization - growth conditions for _Saccharomyces fragilis_. Sewage Indus. Wastes 30: 912-920.

THE DRYING OF WHEY AND WHEY PRODUCTS

H. Young
Kraft Foods Company
500 Peshtigo Court
Chicago, Ill.

The topic of this discussion is the drying of whey, and I should like to expand it to include whey products as well as whey. We must assume that from an economic standpoint, no matter how feasible whey drying may be, it has little value if a market for the final product does not exist. Thus, whey blends, whey plus added ingredients, and whey as a base material for other flavorful and nutritional ingredients are of equal importance to whey alone. Cottage cheese whey falls into a category all of its own, since its high lactic acid level makes this whey very difficult to dry.

Whey production in 1968, the year we have complete records for, is given in Table 1. It is interesting to note that about one-third of the total whey solids produced in the United States is processed as dried whey. However, I am not certain whether these data include those whey solids used in the production of such products as fermented delactosed whey, lactose, and blended products. In any case, an extremely large amount of whey solids goes unprocessed.

TABLE 1.--Cheese and whey production, 1968

Item	Pounds	
Total cheese (excluding part-skim milk and cream cheese)		1,944,000,000
Cottage cheese		1,552,000,000
Cream cheese		114,622,000
Whey solids		
From cheese other than cottage	1,050,000,000	
From cottage cheese	394,000,000	
Total whey solids available		1,444,000,000
Dried whey		498,000,000

In order to discuss logically the drying of whey, we must start considerably earlier than the drier itself. I should like to discuss the basic concepts of drying whey, the procedures used and some of the factors that affect whey drying, the types of driers used, and sanitation and cleaning in the whey plant.

Basic Concepts of Whey Drying

The proper drying of whey, on which the quality of whey products depends, starts considerably before the whey reaches the drier. Proper recovery from the cheese vat, retardation of acid development, proper evaporation of the whey concentrate, and postevaporation handling are all extremely important factors in the drying of whey.

In terms of proper recovery from the cheese vat, most of the cheese processes call for the drawing of all whey at an acidity ranging from 0.10 percent lactic acid for Swiss whey to 0.16-0.18 percent for Cheddar types. The type of starter organisms used is a large factor in the processing of whey. For instance, certain types of cheese, such as Swiss, Parmesan, and Romano, use thermophilic (heat-loving) organisms. These require considerably higher heat treatment to stop the development of acidity than the straight Cheddars which utilize Streptococcus lactis organisms. Thus, the amount of heat required to control acid development in the raw whey immediately after it is removed from the vat is a function of the type of cheese manufactured and the type of starter organisms used.

Whey Drying Procedures

Figure 1 is a flow diagram of the steps in processing whey from the cheese vat to the evaporator. The whey is immediately removed from the vat and goes into a small settling tank to settle out curd particles. It can go to a curd saver, which is somewhat like a sifter, to remove any small curd particles which might be present in the whey. The whey then immediately goes to a

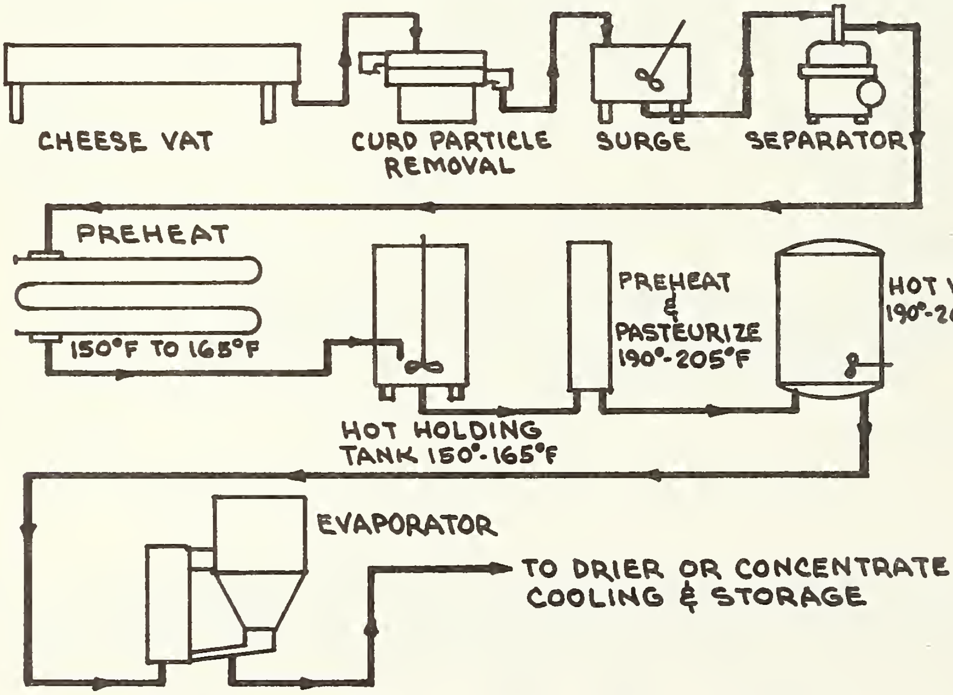
CHEESE VAT
CURD PARTICLE REMOVAL
SURGE
SEPARATOR
PREHEAT
150°F TO 165°F
HOT HOLDING TANK 150°-165°F
PREHEAT & PASTEURIZE 190°-205°F
HOT WELL 190°-205°F
EVAPORATOR
TO DRIER OR CONCENTRATE COOLING & STORAGE

Figure 1.--Processing of whey from cheese vat to evaporator.

separator where the butterfat is removed. Then it goes through a preheater that raises its temperature to 150-165° F. to inhibit bacterial growth and subsequent acid development. At this stage, the whey can be held. The lower temperatures can be used for holding whey from Cheddar, and the higher temperatures for Italian and Swiss types of cheese whey.

The whey goes into a hot holding tank and is held at these temperatures until it goes to the evaporator. This whey can be held for some time without any browning effect on the whey itself. We have held whey in the raw condition for 10 to 12 hours without any deterioration of quality. However, it must be emphasized that this is only in the raw, unconcentrated stage. The whey then goes from the hot holding tank to a hotwell through a preheater which raises the temperature from 150-165° to 190-205° F. Before entering the hotwell, the whey can be pasteurized by passing it from the preheater through a holding tube and timing pump with a flow diversion valve.

The hotwell and the hot holding tank must have proper agitation. Whey protein will precipitate at 160-165° F., depending upon the season. If no agitation is provided, the protein will fall to the bottom of the tank, resulting in a sludge that will not enter the evaporator, or if it does, will enter in such a concentration that it will coat the tubes on the steam chest. This could slow down the evaporation rate or, for that matter, plug the evaporator. At the hotwell and the preheater, the proper conditions for good spray drying are created. For good drying, whey protein must be denatured. At the same time, the lactose must have a heat shock which will result in proper crystallization of concentrate. It is entirely possible to evaporate whey at a low temperature and get no crystallization, even at a 50 percent solids level. Without crystallization, drying is very difficult in certain types of operations.

From the hotwell, the whey goes into the evaporator where standard first-effect temperatures run from 170° to 185° F., and second-effect temperatures from 125 to 135° F. Some plants have triple-effect evaporators; others have double-effect evaporators with finishing pans; still others have double-effect evaporators with recompression. All of them tend to give a good result.

In terms of the total solids, the whey can be evaporated or condensed to anywhere from 40 to 50 percent solids or higher, depending upon the drier and its capability of handling various solid levels. Needless to say, the higher the solids, the faster the drying. Economically speaking, it is cheaper to take water out of a product by vacuum evaporation than it is by spray drying. Thus, the higher the solids, the lower the cost of operating.

The whey concentrate comes from the evaporator at about 125-135° F. If it is going to be dried immediately, it need only go through a surge tank to the drier. If it is to be crystallized, the concentrate goes into a whey concentrate tank where it is immediately cooled to 40° F. and held cold under agitation to allow for proper crystallization. Generally speaking, the drying technique is of less importance than the prehandling of the whey prior to the time it gets to the drier.

One of the factors to be considered in drying whey and whey products is whether or not the whey should be crystallized. From an economic point of view, it is cheaper to take the whey immediately from the evaporator and put it through the spray drier. From a quality point of view, a less hygroscopic powder can no doubt be obtained by crystallizing the whey, holding it cold, and then spray drying it. Whether or not to crystallize the whey would depend upon the individual operator, the type of equipment he has or can purchase, and the ultimate use of the powder itself.

Thus there are basically two types of drying for whey and whey products (see Figure 2): one-stage and two-stage drying. In one-stage drying, the concentrate is pumped through a spray nozzle or spray wheel, the particles going through an air stream and dropping out at the bottom or side of the drier. In two-stage drying, the particles are conveyed from the drier (at approximately 6 to 14 percent moisture) to a secondary drum for redrying (Figure 3).

Whey concentrate that goes directly from the evaporator to the drier will make a highly hygroscopic powder that will tend to cake in the warehouse if not protected from moisture. This hygroscopicity can be minimized by cooling and crystallizing the concentrate before drying it.

For a nonhygroscopic powder, the drying should be done in two stages. In a two-stage drier, a conversion belt or conveyor moves the high-moisture powder from the first stage to the secondary drum at such a rate that the lactose crystals pick up the water of crystallization and then go into the secondary drum for final drying. At this point, the powder becomes nonhygroscopic. It will also remain free-flowing at a proper moisture level.

Instead of a conveying belt, some box-type driers can be arranged so that the powder lies on the floor of the box until it has picked up the water of crystallization, and then the powder is swept down into a secondary drum. Certain precautions should be observed here that will be discussed later. This is a patented process.

There are certain limitations on the temperatures of drying. Generally, the higher the inlet air temperature, the faster the rate. However, with these higher temperatures there are also more chances of scorching and browning.

If the warm concentrate goes to the drier from the holding tank or surge tank, it could be preheated on the way, just as skim milk is. Of course, this would make a hygroscopic powder if dried in a single stage. If two-stage drying is used, a long belt is needed to convey the moist powder to the secondary drum, so that the product will have time to absorb the water of crystallization on the way.

In drying from the cold crystalline concentrate, only mild prewarming, to a temperature not exceeding 100° F., should be used. Higher temperatures melt the crystals, resulting in a sticky powder.

The final powder must be free-flowing, and white to slightly pink in color, depending on the cheese from which it comes. The titratable acidity of a 9-gram sample (when reconstituted using 6.5 grams of powder and 100 cubic centimeters of water) should range from 0.08 to 0.14 percent, again depending on the type of cheese. This is lower than that of the whey as it comes from the cheese vat because of loss of acidity along with the water during evaporation and drying. Sediment should not exceed that equivalent to a No. 2 pad.

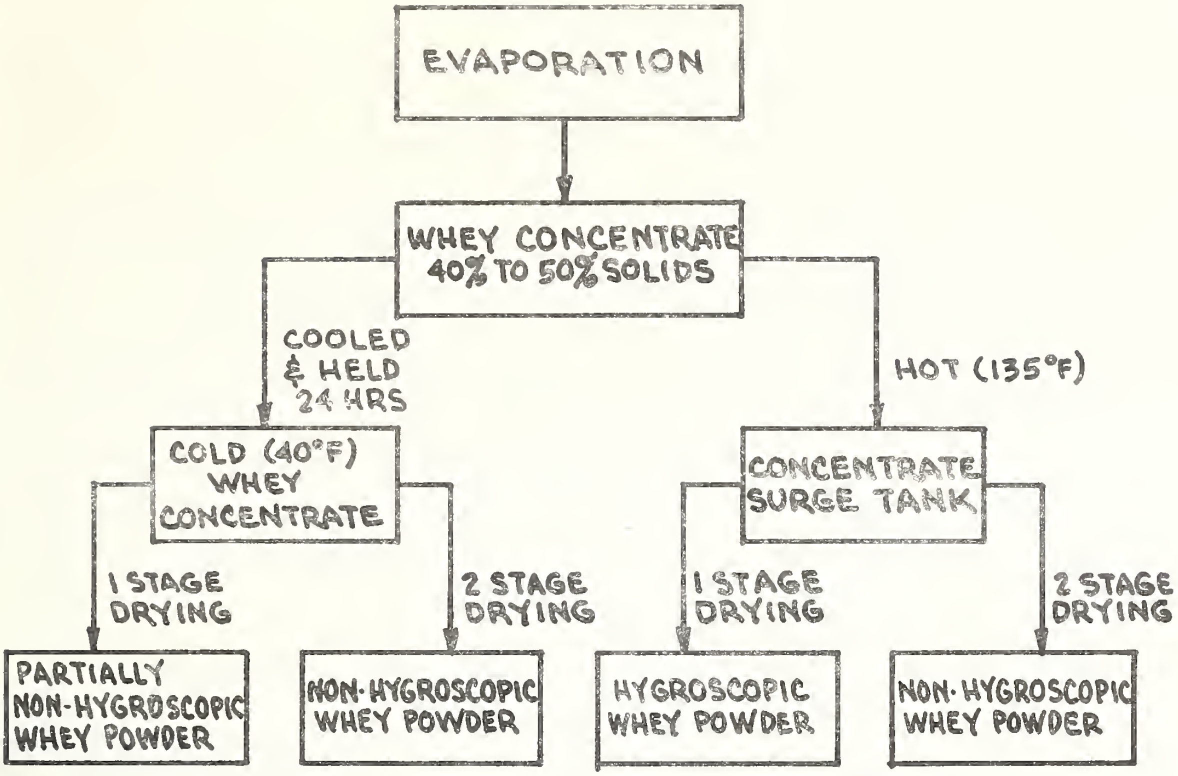
EVAPORATION
WHEY CONCENTRATE 40% TO 50% SOLIDS
COOLED & HELD 24 HRS
HOT (135°F)
COLD (40°F) WHEY CONCENTRATE
CONCENTRATE SURGE TANK
1 STAGE DRYING
2 STAGE DRYING
1 STAGE DRYING
2 STAGE DRYING
PARTIALLY NON-HYGROSCOPIC WHEY POWDER
NON-HYGROSCOPIC WHEY POWDER
HYGROSCOPIC WHEY POWDER
NON-HYGROSCOPIC WHEY POWDER

Figure 2.--Types of whey drying.

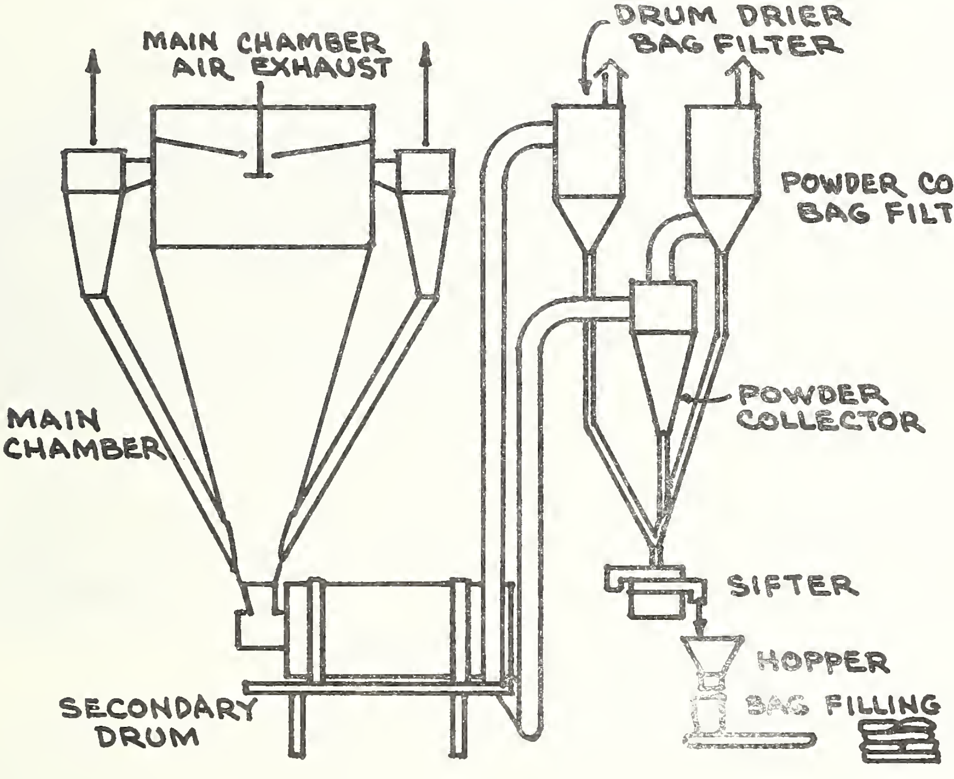

Figure 3.--Two-stage drying of whey.

Thus the quality of whey powder is a function, not only of the drying, but of the handling of the raw whey from the cheese vat and the condensing techniques as well.

Cottage cheese whey falls into a class of its own. Its acidity from the cheese vat will be in the range of 0.45 to 0.55 percent. On a dry solids basis, this can be as high as 9 percent, which is quite high. If cottage cheese whey is handled in the drier in the same way as skim-milk concentrate is, we can fully expect to strike out on any drying operation.

Cottage cheese whey should be handled just as standard whey is, as far as inhibiting the acid with heat, preheating, pasteurization, and evaporation are concerned. However, in this case the product cannot be dried hot directly from the evaporator. To dry it at all, the product must be crystallized. This means that it can be concentrated to about 40 to 50 percent solids, immediately placed in a cold-wall tank with agitation, and cooled to 40° F. and held for at least 24 hours. After crystallization, the product can be spray dried. However, the type of drier is important here.

Types of Driers Used for Whey

I should now like to discuss types of driers that are presently available and can be used for the drying of whey. I have no preferences in this respect. We manufacture our own driers to our own designs, and use them throughout the country. In terms of other driers for whey, each individual must make up his own mind relative to what will best suit him.

Horizontal driers include the box type or the center-auger type. It should be pointed out that the horizontal drier can probably be used for whey if great care is taken. I caution people using this type because of the internal socks (bag filters) which are part of the drier. Whey, being a rather sticky material, has a tendency to hang on the bags and eventually plug them. The result is that at the end of the day, or earlier, all of the bags have to be replaced or washed. Generally speaking, if a box-type drier is to be used for whey alone, it is best to remove the socks and install an outside cyclone collector. Then the exhaust air can be conveyed from the cyclone collector through a sock filter. In addition, it helps to precrystallize the whey concentrate so that if bag filters are used inside the chamber, they do not coat as fast. The horizontal drier with the center auger can be used for drying whey, but again, the whey should be dried from the crystalline form.

Of the vertical driers on the market, some are one-stage and some are two-stage driers. All the one-stage driers appear to give satisfactory results. One company has produced a vertical drier with a secondary reheat system and a vertical drier with secondary drum (Figure 3). There are slight variations between the vertical driers; one is based on a spray nozzle, while the Kraft drier and another have spray wheels.

There has been nothing basically new in the drying area for quite some time until recently, when the Pillsbury Company patented a new type of drier This drier is based on a process which combines spray drying with through-flow continuous bed drying. Figure 4 gives some idea of how the drier works. The concentrate is sprayed in a hot-air chamber for the first-stage drying. The

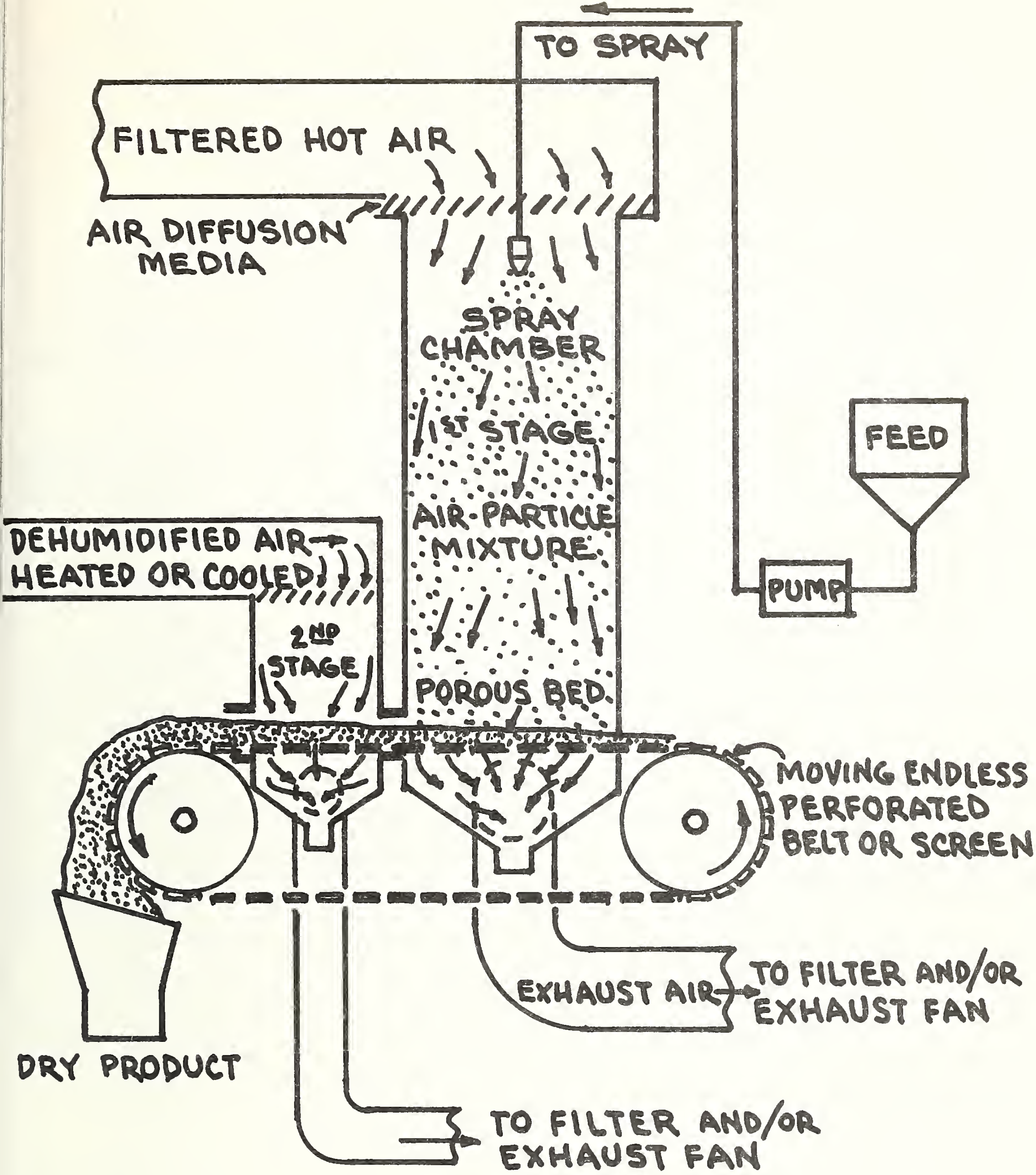

Figure 4.--Combination spray drier and continuous-bed drier.

particles descend to a continuous porous belt that conveys them to another chamber where the second stage of the drying is done with heated or cooled dehumidified air which moves through the porous bed. The powder falls from the belt into a packaging bin. This drier appears to produce a whey powder that is quite acceptable in all respects.

Sanitation and Cleaning in the Whey Plant

No discussion of driers and drying is complete without a discussion of sanitation and cleaning. In terms of sanitation, we must emphasize total plant sanitation and housekeeping. Edible spray-dried products are most susceptible to airborne contamination. Thus, every effort must be made to control the environment in which powders are produced. Quite a bit has been written and spoken on this subject. It is sufficient to say that the following are extremely important:

1. Limitation of nonessential visitors in any plant.

2. Footbaths containing a quaternary ammonium compound to sanitize the bottom of shoes must be at all entrances to the plant. This will control foot-borne contaminants.

3. Air filtration, both for drier rooms (environmental air) and for the air that touches the product.

4. Sealed systems so that powder is not subjected to exposure in the room. Product conveyor belts must be covered.

5. Screens on windows and other features of good sanitation and housekeeping.

6. Good testing program to protect against infection by Salmonellae and Staphylococci. Environment and finished products sampled weekly.

These are all factors in quality product production.

In terms of cleaning and clean-up, a cleaning procedure and schedule must be prepared and adhered to. Quality of clean-up must be checked.

In summary, the production of high-quality spray-dried whey and whey products primarily depends upon:

1. Pre-evaporation control.

2. Proper heat treatment both for drying and bacteria control.

3. Good evaporation techniques.

4. Good drying technique and sanitary practices.

With these in mind, a good, high-quality powder can be made at the proper cost.

Discussion

QUESTION: What concentration does one feed to the dryer?

MR. YOUNG: At Kraft, we operate at 50 percent solids. I know others operate at 40, some at 45.

QUESTION: To get to 50 percent solids, is all the water removed by vacuum evaporation?

MR. YOUNG: Yes.

QUESTION: If you are collecting whey from a number of factories, do you cool it at the factory or try to bring it in hot?

MR. YOUNG: That's been a bone of contention for quite awhile with us. Ken Ward says it has to be refrigerated, and I say it doesn't have to be. Since he's done it with refrigeration, I'd go the refrigeration route, but we have held it up to 10 hours without any deteriorating effect at all.

QUESTION: Do you neutralize at all?

MR. YOUNG: No.

QUESTION: Is this high-acid whey?

MR. YOUNG: This is sweet whey. High-acid whey would probably brown so that I would be very careful about holding a whey such as cottage-cheese whey for that long a time.

QUESTION: In the crystallization process, do you pasteurize first or after crystallization?

MR. YOUNG: We pasteurize prior to evaporation and then we crystallize so that the pasteurization process takes place in the raw whey. Then it's evaporated to 50 percent solids, crystallized, and then spray dried.

QUESTION: Do you recommend that acid whey be neutralized?

MR. YOUNG: Our experience has been that if you try to neutralize acid whey you're asking for more trouble. It's been done, and you can probably make a dried product which is fair. I wouldn't recommend it. If you are going to dry at all, you might just as well try to get high-quality product.

QUESTION: Do you transport the concentrated whey to the drying plant?

MR. YOUNG: Yes, we operate with what we call satellite cheese plants and a central drying location. We have evaporators in every plant, and we concentrate the whey to 50 percent solids, cool it to 40° F., and then transport it to the drying location at the 50-percent solids level. Then we spray-dry it.

QUESTION: Do you have trouble with crystallizing in the tanks?

MR. YOUNG: At times. Not all the time. At the 50-percent level the viscosity is quite high, so that the settling rate is quite slow. If it's thin and rather watery, you'd probably get some crystallization. But at the 50-percent solids level we don't have too much of a problem with that.

QUESTION: Is the denaturing of the protein a critical factor?

MR. YOUNG: Yes.

QUESTION: Is protein denaturation necessary in whey drying?

MR. YOUNG: Proper heat treatment of the whey is necessary to get crystallization of the lactose, and while you are doing that you are also denaturing the protein.

QUESTION: Is the water which is evaporated from the whey ever returned to the plant for process water?

MR. YOUNG: Yes. That's excellent water and we use it for the boilers.

QUESTION: Is the speed of cooling critical?

MR. YOUNG: Yes, within limits. The faster you can cool, the more crystals you get, and the finer these crystals are. You're not making lactose in this particular case, you're asking for a carrier. So you need a lot of crystals, and the faster you cool, the better off you are.

QUESTION: Is there a maximum amount of time that the concentrate remains in the tanker?

MR. YOUNG: We try to keep it there as short a time as possible. That's not realistic, because, at times, we haul concentrate from long distances--as much as 300 to 500 miles. That could be 10 to 15 hours. Of course, this is unusual. We couldn't afford such long hauls on a regular basis.

The Conference Dinner Speech

FOLKLORE, STATISTICS AND ECONOMICS OF WHEY

H. C. Trelogan
Administrator, Statistical Reporting Service, USDA
Washington, D. C.

Ever since I can remember, whey has been cited as a latent resource in the dairy industry that offered great opportunity. In other words, it represented a rainbow in the sky, presumably with a pot of gold at the end. The trouble was that whey stinks if it is neglected for long. This general prospect seems to prevail still. This conference symbolizes hope that gold may yet be found out there in the years stretching ahead.

I find it encouraging that scientists are willing to pursue this rainbow again. Upon my last reading, shortly after World War II, the American Dairy Science Association proposed to disband its byproducts committee that had a more exhaustive utilization of whey as one of its major objectives. I managed to breathe life into the committee for only one year before it expired. My advocacy for continuing the committee was based entirely on need for scientific help to deal with ominous problems. The fact that my enthusiasm was not shared could not be attributed to opposition, but only to a lack of promise for relevant scientific breakthroughs.

The need still exists, and the incidence of this conference suggests that the promise of progress is more virile now. I hope that is true, but my current reading leaves the strong impression that present motivations may be emanating from an accentuation of need stemming from greater public concern about pollution.

Maybe I can contribute to a broader perspective. Imaginative ideas are sorely needed. Who knows from where they originate?

Byways of Whey

Every child knows that humans can eat whey, at least he knows that Miss Muffet enjoyed whey along with her curds. But very few people are familiar with other references to whey to be found in Anglo-Saxon literature. Let me cite a few, because they indicate a variety of reasons for consuming it that just could be suggestive to an advertising agency. Samuel Pepys was a whey drinker, and in his Diary for June 10, 1663, he mentioned going to a wheyhouse after the theater. Sir Walter Scott also enjoyed the beverage but not, apparently, because of its own virtues. He reported in a letter that, while staying with his uncle, he had begun to drink whey upon discovering that it "was brought to his (uncle's) bedside every morning at six, by a very pretty dairy-maid." In 1732, John Arbuthnot, in a book called An Essay Concerning the Nature of Ailments, and the Choice of Them, According to the Different Constitutions of Human Bodies, maintained that "Of all Drinks, Whey is the most relaxing." It is apparent that some illustrious names could be called up to support a public relations campaign for whey.

Even stronger testimony comes from other and older literature. For example, in 1761, an M.D. named Frederick Hoffman wrote a "Treatise on the Virtues and Uses of Whey." (By the way, he was physician to his Majesty the King of Prussia.) The treatise opens with: "There are few fluids more salutary, and better adapted to prevent, and cure the diseases of the human body than whey." He cites "the most ancient and learned physicians"from Greece one of whom states: "Whey, when separated from the grosser parts of milk, is a more effectual purge, and is given to those whose bodies we would render soluble without recourse to acrimonious substances, such as persons afflicted with melancholy, leprosy, the elephantiasis, or eruptions over the whole body." Quotations from Hippocrates are prominent and advocate the use of whey for extended periods and for other maladies such as scurvy.

Another ancient writer brings in the factor of quality when he says: "Whey of goat's milk is in itself an innocent medicine; and that species is best which is made from the milk of black goats, who feed in good pastures, and have lately brought a kid."

One can only conclude that from ancient times the medics have known that whey had something. According to English literature, whey seems to have usually been consumed as a beverage, but this was not always the case. Wheyborse was a broth made with whey; whey porridge was similarly concocted; wheybutter was butter made with either whey or whey-cream (the cream remaining in whey after separation). For those who liked none of these, but wanted a more exciting drink than simple whey, there was whey-whig made with a whey base and herb seasoning.

Whey, of course, can be fed to some livestock. There is a reference dating from 1600 recommending it as a part of the diet of pigs and dogs; and in his 1893 study of British dairying, J. P. Sheldon mentioned that on dairy farms, "pigs are useful to consume whey and skim milk."

Unfortunately, the record is thin when it comes to the possible health-giving benefits of whey, but it is not entirely lacking. In 1820, a Dr. Wirer discovered the advantages of the mineral springs at Ischl in Austria which later became the summer residence of the Empress of Austria. Wirer began to develop a resort at Ischl, and he made provisions for supplying whey to his guests on the theory that it supplemented bathing in the mineral waters. Some years later, 1888, William Fraser Rae, a commentator of the spas of Austria and Hungary, noted that some visitors to Ischl had known a good thing when they saw it. As he said: "The spoiled daughters of luxury who are very rich and have very sensitive skin, indulge in whey baths. Such baths are supposed to calm the nervous system; but their use may be chiefly due to the fact that they render the skin soft to the touch and silky in appearance."

Today, whey is probably best known among the general public, not as a food, beverage, or bathing media, but as an adjective. At various times in history, the woodlark has been known as the whey-bird and people have been described as whey-blooded (cowardly), whey-brained (weak-minded), and, of course, whey-faced. The term "whey-faced" has an honorable tradition, going back at least to Samuel Foote's play, "The Englishman in Paris" of the 1750's.

The Oxford English Dictionary indicates that since the birth of the

English language, the word whey has had nine distinct forms and fifteen different spellings. It has traveled a typically circuitous linguistic route from Teutonic and Middle Dutch, through Anglo-Saxon and Middle English, down to its present form. Over the years, the word and the substance it represents have gained a secure, if very small, place in our language and culture.

Why do I bring this up? Surely we will all concede that whey occupies a minority position among dairy products. As is the fashion with minority groups these days, consideration might be given to alterations of language and literature.

Here we might take a lesson from dried skim milk. Although the term non-fat dry milk solids had been advocated by some dairy evangelists for some time and legislation for this name change was lying in Congress, nothing would have happened without an incident. President Franklin D. Roosevelt and Secretary of Agriculture Claude Wickard were looking for a way to assuage the bruises caused when they rejected proposed price increases for whatever you wanted to call it. This legislative bill was pulled out of the hopper and passed to divert attention. To my knowledge, and I suspect it is unfortunate, we have never had a cost-benefit ratio analysis applied to this matter. Advantage attributable to this thought must still be regarded as conjectural.

Some Statistics

Let me turn for a moment from conjecture to statistics; from folklore to facts. Dry whey statistics have been collected by the Statistical Reporting Service (SRS) since 1937 -- condensed whey since 1954. Dried whey production has shown a marked upward trend ever since the statistics have been collected, from a low of 47 million pounds in 1938 to 499 million pounds in 1968. Declines following 1955 and 1960 marked the only two interruptions in this rather steady trend. Condensed whey, on the other hand, dropped from 189 million pounds in 1954 to 86 million pounds in 1962, hit a peak of 194 million pounds in 1966, and fell to 158 million pounds in 1968.

Since 1955 the increased production of dried whey has accompanied greater production of cheese and has been marked by greater outputs per plant. Average output per plant in 1968 was 4.7 million pounds compared with 1.3 million pounds in 1938. Since 1962 the output of condensed whey per plant has more than doubled, running around 5 million pounds in recent years.

Lactose production has increased more than 10-fold in the last 25 years, with crude milk sugar production in 1968 about 83 million pounds. Refined lactose production, for which statistics are not generally available, would be in addition.

Some Economics

From the available data my analysis indicates that hardly half the potential supply of liquid whey is used in the manufacture of commercial products. Some additional, but unknown, amounts are used for livestock feeding and for fertilizer. A notoriously large amount is wasted. Each of these methods of disposition incurs some severe limitations. The seasonal patterns of whey availability and feed whey demand do not fit. Heavy production of whey occurs in the spring when pigs are little and cannot consume much; it is less available in the fall when the pigs are large and able to use more. So we have to concentrate whey to carry it over both time and space. There is a distinct limit on the amount of whey land can absorb for fertilizer. All three of these methods of disposition encounter sanitation and pollution problems with waste presenting the worst of these.

Most of the liquid whey not used for processing is regarded as a disposal problem and could be made available without cost at the location of production. In fact, much of it offers opportunity for income just to take it away. Ordinarily the idea of getting income for acquiring a raw material for manufacture would appear very attractive.

But some other economics intervene. These dismal factors from the dismal science were brought forcefully to my attention during World War II. One day in 1943, when I had nothing to do but administer War Food Orders intended to extract dairy and poultry products from processors for diversion away from highly attractive domestic outlets to less attractive wartime uses, a secret message arrived from the War Production Board. Arrangements must be made immediately to divert milk sugar to designated plants for war purposes that could not be specified. By the end of one year the annual amounts of lactose to be delivered to these plants would exceed any previous total annual production of milk sugar in this country. Now that sounded like a very nice order for processors of whey, but I soon learned there were a lot of reluctant dragons, and why.

There were two avenues of approach: (1) divert existing production away from current uses, and (2) obtain more production.

(1) Diversion.--The only existing uses of milk sugar were by processors who had been paying a substantial premium for this carbohydrate over prices for readily available sucrose, glucose and other sugars. They had no substitutes for milk sugar or they would have turned to them long before. They represented a diverse group of uses such as powder for making medical pills, special baby foods, fuses and explosives, fuel for smoke screens, and crystals in highly priced choice liquors. Some of these uses were also regarded as essential for military as well as civilian purposes. They took most of the production. We asked the National Academy of Science to help us solve this problem by identifying the less essential uses. After long deliberation by a committee, the naive reply came back that there are very few nonessential uses, so we recommended that the Office of Price Administration raise the prices. That clearly was not the answer -- dried nonfat milk powder prices would have had to be raised too.

(2) Expansion.--Existing producers exhibited little enthusiasm for building new plants or otherwise expanding production. From long experience they had learned about the inelasticity of demand for milk sugar and that a little bit of overproduction caused prices to drop precipitously. They couldn't even be told what the new use was to be, so how could they judge how long it would be wanted. They couldn't afford to expand production and risk the consequences when the war was over. New producers were sought, but they soon learned that the processes were subject to patents held under close control to avoid overproduction.

It took some real persuasion and maneuvering, even with the force of a

War Food Order, to supply the lactose for penicillin. The chief manipulators were Gordon Sprague from government and Reginald Meade from private industry. Production was expanded. After the war, penicillin manufacturers, like good businessmen, tried and found cheaper sources of carbohydrates. Lactose producers, also like good businessmen, developed other markets, and I am most gratified to see the continued upward trend in output.

Much the same factors affect whey utilization generally and the problem is still with us that much greater utilization is still needed. So this conference is very timely.

Several factors are at work that suggest the prospects are not altogether gloomy. Total milk production is declining with a promise of less nonfat dried milk to compete with; the declining output is already evident. Cheese production is trending upward with more whey in prospect, especially from larger-scale plants that may make the procurement problem easier. Public concern with pollution offers the prospect of liquid whey being even a more readily available raw material.

Should you devise less costly processing methods or manage to develop new or broader uses for whey products, the outlook could be regarded as bright.

Yes, this is a timely conference. I wish you success, success in the sense that the conference fosters and implants some novel and productive ideas.

Theme: Uses for Whey

OPENING REMARKS BY THE CHAIRMAN

I. A. Wolff
Director, Eastern Utilization Research and Development Division
Agricultural Research Service, USDA
Philadelphia, Pa.

Since this conference was organized and sponsored by the Eastern Utilization Research and Development Division, I might take a moment to outline the scope of our activities for those who might not be acquainted with our organization. The Eastern Division has its headquarters in Wyndmoor just outside of Philadelphia, Pa., with field locations in Washington, D. C., Beltsville, Md., Waltham, Mass., and East Grand Forks, Minn. The Division consists of 10 research laboratories and is charged by the Congress with responsibility for research on animal products: including dairy, meat, animal fats, and hides and leather; and plant products: including Eastern fruits and vegetables, maple, and tobacco. In addition to whey, the Eastern Division is also interested in the wastes from potato processing and from animal product and byproduct manufacture, and in developing methods for their recovery and utilization.

Yesterday we considered some pollution aspects of the whey situation and problems of whey processing. We also heard discussions of various alternative procedures for reducing whey to more stable forms for preservation, which is, of course,the first step towards utilization. But a really important item for our consideration, a continuing challenge in the 70's, will be to find new and expanded profitable uses for these large quantities of whey--What do we ultimately do with it? As you have heard, progress has been made in the last 40 years. Department of Agriculture scientists, university personnel, and industrial organizations have during this period been conscious of the problem and have been looking for uses for whey. About one-third of the whey produced now finds some usage. This leaves two-thirds--another 14 billion pounds on a liquid basis or just under a billion pounds of solids--that we must find uses for. This will take much more intense activity than has been hitherto devoted to the problem. We are developing the know-how for processing whey, to save it from being dumped. Now this morning we will explore better ways to use the processed product. Included will be coverage of the nutritional aspects, chemical problems, utilization in foods and feeds, and finally a panel discussion of experts that will provide us an overview of the whole field and suggest some courses of action for the future in terms of both research and marketing aspects.

Though most of you are familiar with the composition of whey, it might be well, at the beginning of this session on uses for whey, to review that composition, since it is basic to the consideration of many present and proposed uses. Dried whey generally contains 70 to 75 percent lactose, about 13 percent crude protein (Kjeldahl N multiplied by a factor), 8 percent ash, 3 percent moisture, and 1 percent lipids, with about 0.5 percent of the total nitrogen in the lipid fraction. Table 1 shows some unpublished data obtained by Cerbulis and Woychik, of our Division, on the nitrogen distribution in acid whey, Cheddar and Swiss cheese whey, and 5 samples of sweet whey, as compared to a control laboratory preparation made with skim milk as the raw material.

TABLE 1.--Nitrogen distribution in commercial dried wheys as compared with a control laboratory preparation made from skim milk

Item	Sweet whey samples					Acid whey	Cheddar cheese whey	Swiss cheese whey	Control
	A	B	C	D	E				
pH (10% aqueous solution)	5.8	5.9	5.5	5.9	6.2	4.7	5.6	5.6	4.7
Total nitrogen, percent	2.0	2.2	1.9	2.2	1.9	2.0	1.8	2.3	1.8
Protein, percent (total nitrogen x 6.38)	12.9	13.8	11.9	14.0	11.8	13.0	11.7	14.7	11.6
Nondialyzable nitrogen, percent of total N	76.0	83.7	82.2	76.2	80.5	79.0	77.2	69.0	72.2
"True" protein, percent (nondialyzable nitrogen x 6.38)	9.8	11.5	9.8	10.7	9.5	10.3	9.0	10.1	8.4

NUTRITIONAL ASPECTS OF WHEY AS A FOOD

D. A. Vaughan
Human Nutrition Research Division
Agricultural Research Service, USDA
Beltsville, Md.

I propose to talk today about the possibilities of whey in general as a dietary supplement and also about some of the problems that may arise in its use for that purpose. Specifically, I am most interested in whey as a dietary supplement to low-quality foods which are eaten by a large segment of the world's population. By low-quality foods, I mean primarily grains such as rice, corn, and wheat which either do not provide enough total protein for growth or even for maintenance of man, or which provide proteins that are deficient in some of the amino acids essential for synthesizing tissue protein in man. Can whey, as a supplement, upgrade the quality of these diets by providing extra protein or by filling in some of these amino acids? Although it is true that one would hope that a supplement could provide some of the other nutrients such as vitamins and minerals, I feel that any widespread use of whey as a supplement for human diets will be based on its usefulness in upgrading the protein quantity and quality of the diets. Whey, however, could be useful in providing riboflavin and calcium in particular, as we shall see.

I think most of you would agree that one practical way of looking at the nutritional value of whey is to compare it with dried skim milk, which is already being used in large amounts to upgrade the protein quality of the diet, both here and abroad. It seems likely, to me at least, that if whey is going to be used as a food supplement in large amounts, the first practical step would be as a substitute for nonfat dried milk (NFDM).

How, then, does dried whey compare with nonfat dried milk? Table 1 shows the approximate contents of the major nutrients in these two products. Parenthetically, I should point out that values I have seen given for whey vary

TABLE 1.--Nutrients in dried whey and nonfat dried milk

Nutrient	Approximate content	
	Whey*	Nonfat dry milk**
	Percent	Percent
Protein,	12.9	35.8
Fat,	1.1	0.7
Ash,	8.0	7.9
Water,	4.5	4.0
Lactose,	73.5	51.6

*350 Calories per 100 grams.

**359 Calories per 100 grams.

depending on the type of whey and the source of data, so that all the values I present today are representative only for the purpose of general comparison. As you can see, the total protein content of whey is much lower than that of nonfat dried milk (about 1/3). Not only is the protein level lower, but the types of proteins are different, since the casein of milk is removed during cheesemaking. The proteins remaining in whey are chiefly lactalbumin and lactoglobulin. In milk, of course, the chief protein is casein, and so this difference is reflected in a somewhat different amino acid profile of whey protein as against dried skim milk proteins. We will see how that differs a little later.

Fat content and water content are similar. Total ash content is similar for the two products but this value does not tell us about the specific minerals which might be desirable for human nutrition. A more detailed approximation of the individual minerals is shown in Table 3. The food calories available from the two products are essentially the same, since the total carbohydrate plus protein level adds up to 86-87 percent.

The other major difference in nutritive content of dried whey is, as you can see, the percentage of lactose. As the casein is precipitated out of the milk during cheesemaking, lactose remains in the whey and therefore becomes the major ingredient of the dried product. Now this high lactose content can create serious problems for human feeding. Many groups or populations in this country and abroad cannot tolerate lactose. This intolerance appears to be the result of a genetic trait whereby the intestinal enzyme, lactase, fails to develop.

Some researchers feel that this intolerance to lactose sets in at a relatively early age, i.e., in young school children. In general, intolerance to lactose causes symptoms of bloating, cramps, flatulance, and diarrhea in the individual and leads him to avoid drinking milk and to refrain from giving it to his children. Milk or lactose intolerance is high in Negroes, Orientals, some East Indians, and American Indians. By a high intolerance I mean that 70-90 percent of these people react abnormally to a lactose load of 50 grams per square meter body surface area, whereas less than 20 percent of Caucasians show such an intolerance. Some of these lactose-intolerant people can tolerate low amounts of lactose, for example 12 grams, or the equivalent of a glass of milk. So far, however, it does not appear that adaptation to milk can be induced, although the evidence is not all in yet. Certainly a lot more research is needed in this field, especially with non-Caucasian children, for this population represents a sizable percentage of the very people whose nutrition we are trying to upgrade with milk products as supplements both in this and other countries. And even if actual physiological intolerance is not yet especially high in these children, the likelihood is that their parents, who do have milk intolerance, will resist products which they cannot themselves tolerate.

Table 1 shows that dried whey is at a considerable disadvantage, because in order to supply an equivalent amount of protein, the lactose intake would necessarily be almost 4 times as much as it would be with nonfat dried milk.

Table 2 shows the levels of some of the vitamins in the two products. Dried whey is as good a source of the B-vitamins, particularly riboflavin, as

TABLE 2.--Vitamin content of milk products

Vitamin	NFDM (mg./100 g.)	Whey, dried (mg./100 g.)	Approx. requirement for 10-kg. child (mg./day)
Thiamine	0.35	0.50	0.4
Riboflavin	1.78	2.51	.6
Niacin	.9	.8	6.0
B_6	.40	--	.5
Biotin	.025	.04	--
Pantothenic	3.2	4.8	5.0
Folic acid	.06	.09	.1
Choline	200	200	
Vitamin A (I.U.)	30	50	1,500

milk. Since milk fat has been removed from both products, neither is a very good source of vitamin A. The values tabulated on the last column of the table show approximate requirements for a 10-kilogram child, where we know them. Dried whey would be useful as a source of thiamine for people eating polished rice and a very good source for supplementing all three grains with riboflavin.

In Table 3 is shown the approximate mineral content of these two products as related to the requirement of children. I think it will be apparent that dried whey is a very good source of supplemental calcium, phosphorus, and magnesium for growing children. Dried whey, however, is not as good a source of calcium and phosphorus as is nonfat dried milk. Both products contain various amounts of trace minerals, such as cobalt, copper, manganese, and zinc, which are known to be required for good nutrition.

Many protein-rich mixtures now in use or proposed as supplements for the enrichment of low-protein indigenous diets in underdeveloped areas contain nonfat dried or skim milk as one of the ingredients. The level or percentage often varies from 5 to 10 percent of the mixture. Examples are wheat-based mixtures used in Algeria and Turkey, and corn-soya mixtures, such as CSM, and others. One corn-soya type product which contains whey as well as skim milk is ProNutro, a product manufactured in South Africa by Hind Brothers and Company, Durban. Its composition is shown in Table 4. This is probably a rather expensive product, because the item listed as "other concentrate" consists of wheat germ, Torula yeast, fish protein concentrate, and malt-extract solids. At any rate, 100 grams of ProNutro, which in its present composition contains both nonfat dried milk and whey powder, would provide 20 grams of protein and 9.6 grams of lactose.

TABLE 3.--Mineral content of milk products

Mineral	NFDM (mg./100 g.)	Whey, dried (mg./100 g.)	Approx. requirement for 10-kg. child (mg./day)
Calcium	1293	646	600
Iron	0.6	1.4	10
Magnesium	100	130	100
Phosphorus	1005	589	700
Potassium	1725		400
Sodium	526	700	400

TABLE 4.--Composition of ProNutro and effect of adding more whey in place of NFDM

Ingredient	Content (g./100 g.)	Protein in ingredient (g./100 g.)	Lactose in ingredient (g./100 g.)
Cornmeal	38.6	3.55	--
Soybeans (dehulled)	17.7	6.04	--
Peanuts (dehulled and shredded)	14.0	3.67	--
NFDM	10.0	3.60	5.2
Whey powder	6.0	.78	4.4
Sugar	4.1	--	--
Other concentrate and minerals	9.6	2.38	--
Total	--	20.02	9.6
Total with NFDM replaced by whey powder (16 percent whey)	--	17.72	11.7

If, instead of a combination of nonfat dried milk and whey, we used dried whey as the sole source of the milk-derived ingredients, we would have a mixture containing 16 percent whey. As shown on the last line, this would provide 2.3 grams less total protein and 2 grams more lactose in 100 grams of the ProNutro mixture. The increase in lactose content is perhaps not a very serious defect in the new mixture, for the total amount in 100 grams is still only about as much as is found in a glass of milk. The reduction in protein content, however, means that we would now have a product that does less from the standpoint of its purpose, that is, to provide protein supplementation, than it did before. It would still be a good source of protein, though, and might be justified on other considerations such as cost or the relative availability of whey and nonfat dried milk.

In Table 5 I have applied the same calculations to the widely used corn-soya-milk mixture - CSM - which is being used as a protein-rich food in various areas of the world and is now recently being piloted in the United States.

TABLE 5.--Composition of CSM and effect of replacing NFDM with whey

Ingredient	Content (g./100 g.)	Protein in ingredient (g./100 g.)	Lactose in ingredient (g./100 g.)
Cornmeal	68	6.30	--
Soy-defatted	25	11.75	--
NFDM	5	1.80	2.5
Minerals + vitamins	2		
Total	--	19.85	2.5
Total with NFDM replaced with 5 percent whey	--	18.70	3.6

Nonfat dried milk constitutes 5 percent of the CSM mixture and the total protein content is 19.8 percent. In 100 grams a person would get 2.5 grams of lactose, certainly a negligible amount, for even if a lactose-intolerant adult were to eat 300 grams per day of the mixture, which would provide adequate protein intake, his total lactose intake would be less than 10 grams. Now if dried whey was substituted for nonfat dried milk in the CSM mixture, the final concentration of protein and lactose would be 18.7 percent protein and 3.6 percent lactose. As with ProNutro, inclusion of whey lowers the total protein somewhat and raises the lactose content, but the product would still be a good source of protein and the lactose content is still within limits that could be handled by a lactose-intolerant individual.

These two examples, of course, are simply projections based on average book values given for these products. Whether acceptability would be a problem I do not know. Only by experimental and field testing would one know if the substitution of whey for nonfat dried milk would be practical in products that are to be used to enrich the protein content of inadequate diets.

With that "caveat" firmly in mind, however, let us explore the possible nutritional characteristics of whey a bit further.

When we talk about supplementing a diet inadequate in protein, we are not only concerned with increasing the total amount of protein in the diet, but also we are concerned with increasing the quality of protein in the diet. Quality of protein, as nutritionists regard it, means the amounts of the essential amino acids which the protein contains. Essential amino acids are those tissue protein building blocks which cannot be synthesized in sufficient amounts by the body to build tissue protein and which therefore must be supplied as such by the diet. When we talk about the daily requirement for these essential amino acids, we mean how much must be eaten in an available form, i.e., in protein or as free amino acids.

Table 6 illustrates how nonfat dried milk and dried whey compare with respect to these essential amino acids. In the third column headed "RO whey" I have projected values which would be approximated if whey was treated by the reverse osmosis method which is being developed by Frank McDonough, of the

TABLE 6.--Essential amino acid content of milk products

Amino acids	NFDM (g./100 g.)	Whey, dried (g./100 g.)	RO whey (g./100 g.)	Approx. requirement for 10-kg. child (g./day)
Histidine	0.937	0.175	0.490	0.320
Isoleucine	2.271	.716	2.004	.900
Leucine	3.493	1.039	2.909	1.500
Lysine	2.768	.936	2.620	1.050
Methionine	.870	.264	.739	.650
Total sulfur amino acids	1.188	.554	1.551	1.150
Phenylalanine	1.724	.368	1.030	.900
Threonine	1.641	.726	2.032	.600
Tryptophan	.502	.230	.644	.220
Valine	2.444	.716	2.004	.930
Tyrosine	1.814	.221	.618	--
Total protein	35.6	12.7	35.6	--

Dairy Products Laboratory. These projected values are based on the assumption that the whey protein concentration in the final product would equal the protein concentration of nonfat dried milk and that the final lactose content would also approximate that of nonfat dried milk. In the last column I have tabulated the estimated daily requirement of a one-year-old child. I hope this will give you a frame of reference for examining the relative amino acid content in 100 grams (about 3 1/2 ounces) of the different milk products. This amount would also provide about 30 percent of the daily caloric requirement for a child of this age.

Looking, then, at the essential amino acid profile of nonfat dried milk, we can see that 100 grams provides these compounds in amounts well above the daily estimated requirement for a child.

One hundred grams of dried whey, as shown in the next column, has much lower concentrations of these amino acids, and only threonine and tryptophan would be present in adequate amounts to meet the daily requirement of a child. The main reason for this, of course, is the low total protein content of dried whey. However, if the whey proteins are concentrated to a level equal to that of nonfat dried milk, as shown in the third column, the amino acid profile becomes quite favorable. It is different from that of nonfat dried milk, because whey proteins are predominately lactalbumin and lactoglobulin, while casein is the main protein in nonfat dried milk. RO whey, as I shall refer to it, contains more of the sulfur amino acids, more threonine and more tryptophan and less of the other essential amino acids.

With the concept of essential amino acids in mind, let us look again at the corn-soy-milk, or CSM product, and see how its essential amino acid profile looks when the three milk products are used.

In Table 7 I have listed the essential amino acids on the left and in the next columns the amounts of each which are contributed to 100 grams of CSM by 25 percent soy, 68 percent corn, and 5 percent nonfat dried milk, or 5 percent whey, or 5 percent RO whey. Then, in the columns headed "total" I have tabulated what would be the essential amino acid content of 100 grams of CSM if the three products were used interchangeably. If whey powder was used at the 5 percent level, 100 grams of the product would be low in total sulfur amino acids and marginal as far as lysine and tryptophan were concerned. With nonfat dried milk and RO whey, both lysine and tryptophan would be supplied in adequate amounts. Sulfur amino acids would still be low with either combination. The drop in the essential amino acids--lysine, methionine and cystine, threonine, and tryptophan--of the CSM with dried whey would calculate to be about the same as the drop in total protein shown in Table 5. This disadvantage would be removed by using a whey preparation in which the protein level was similar to that of nonfat dried milk.

Now I want to give you some idea of the supplemental protein or actually essential amino acid possibilities of whey and concentrated whey or RO whey for diets consisting of rice, corn, or wheat, the major grain foods eaten in developing countries. One is mainly concerned about supplementing these foods with the amino acids lysine, methionine and cystine, threonine, and tryptophan; and I have considered only these amino acids. Bear in mind, also, that the data are simply based on published analytical values; actual samples

TABLE 7.--Essential amino acids in CSM

Amino acid	Standard CSM				CSM with NFDM replaced with:				Approx. requirement for 10-kg. child (g./day)
	25% soy (g./100 g.)	68% corn (g./100 g.)	5% NFDM (g./100 g.)	Total (g./100 g.)	5% whey (g./100 g.)	Total (g./100 g.)	5% RO whey (g./100 g.)	Total (g./100 g.)	
Histidine	0.792	0.129	0.046	0.967	0.009	0.930	0.025	0.946	0.320
Isoleucine	.657	.290	.113	1.060	.036	.983	.101	1.048	.900
Leucine	.933	.810	.174	1.917	.062	1.805	.174	1.917	1.500
Lysine	.773	.180	.138	1.091	.047	1.000	.132	1.085	1.050
Methionine	.164	.116	.043	.323	.013	.293	.036	.316	.650
Methionine + cystine	.381	.197	.059	.637	.028	.606	.078	.656	1.150
Phenylalanine	.604	.284	.086	.974	.019	.907	.053	.941	.900
Threonine	.481	.249	.082	.812	.036	.766	.101	.831	.600
Tryptophan	.168	.038	.025	.231	.012	.218	.034	.240	.220
Valine	.642	.319	.122	1.083	.036	.997	.101	1.062	.930

could vary widely. Even more important, the availability of these amino acids to the human may be considerably less than 100 percent, depending on digestibility, on destruction during cooking or processing, or on the formation during processing of complexes between these amino acids and other nutrients that might render them impervious to digestive enzymes. All these possibilities should be tested in humans, or at least in lower animals, before any definite statements are made about a particular mixture. So what is shown is a "suppose" situation, really the first of many steps in working out a diet which might provide a better amino-acid profile.

Table 8 shows the amounts of these amino acids provided by 300 grams (a calorically adequate quantity) of each of the three major grains, rice, corn, and wheat. Then it shows the amino acids that would be provided by 250 grams of each cereal, supplemented with either 50 grams of dried whey or 20 grams of RO whey. As a point of reference, again I have used the estimated requirements of a 10-kg. child.

In the case of rice, 300 grams without supplementation would be low in lysine and the sulfur amino acids. With whey added, rice is well over the requirement for lysine. The sulfur amino acids, although improved, are still somewhat low, while threonine and tryptophan are boosted to well above the required levels.

With cornmeal, 300 grams provides inadequate amounts of lysine, sulfur amino acids, and tryptophan. The whey supplement provides enough lysine and tryptophan for 250 grams of cornmeal to meet the requirements for these amino acids and to come close with the sulfur amino acids. The lactose contribution of the whey supplement is, of course, the same for each cereal.

The values shown for wheat are those for white flour. Three hundred grams is quite "deficient" in lysine and low in sulfur amino acids. Supplementation with the whey products would raise the lysine level of 250 grams of wheat to meet the daily requirement for a child, and would make this amount of the grain nearly adequate in sulfur amino acids.

Now all of these calculations are based on the assumption that the essential amino acids in whey and the basal grain diets are available to the human. In other words, they assume that the digestive enzymes can release them from the protein molecule or any other complex that may have formed during commercial processing or home cooking. In 1955, Riggs, Beaty, and Mallon (_5_) showed that the digestibility of spray-dried whey was much higher than that of roller-dried whey, 95 _versus_ 78 percent, and also that the biological value, that is, the percentage of nitrogen absorbed that was retained, was higher: about 90 _versus_ 80 percent. This loss in nutritive value was partially corrected for by adding lysine to the diet. Kraft and Morgan (_3_) in 1951 showed that dry skim milk autoclaved for 15 or 25 minutes, which was found to have lost nearly all protein value for rats, was not improved by supplements of methionine alone but was largely restored to normal by supplements of lysine alone or lysine with other amino acids.

Hodson (_2_), however, claims that the amino acid deficiency of evaporated milk proteins for rat growth involves mainly the sulfur-containing amino acids.

TABLE 8.--Whey as a supplement for cereal grains

Grain and amino acid	300 g. cereal (g./100 g.)	250 g. cereal (g./100 g.)	50 g. whey* or 20 g. RO whey** (g./100 g.)	Cereal + whey or RO whey (g./100 g.)	Requirement for 10-kg. child (g./day)
A. RICE					
Lysine	0.900	0.750	0.468	1.218	1.050
Methionine	.411	.342	.132	.474	.650
Methionine + cystine	.720	.600	.277	.877	1.150
Threonine	.894	.745	.363	1.108	.600
Tryptophan	.246	.205	.115	.320	.220
B. CORNMEAL					
Lysine	0.795	0.662	0.468	1.130	1.050
Methionine	.513	.427	.132	.559	.650
Methionine + cystine	.870	.725	.277	1.002	1.150
Threonine	1.101	.917	.363	1.280	.600
Tryptophan	.168	.140	.115	.255	.220
C. WHEAT					
Lysine	0.717	0.598	0.468	1.066	1.050
Methionine	.414	.345	.132	.477	.650
Methionine + cystine	1.044	.870	.277	1.147	1.150
Threonine	.906	.755	.363	1.118	.600
Tryptophan	.387	.322	.115	.437	.220

*36 g. lactose

**10 g. lactose

Amino groups can react with aldehyde groups of reducing sugars--lactose is a reducing sugar--and thus prevent release of lysine and possibly other amino acids. Back in 1948, Henry and Kon (1) found that when high moisture (7.6 percent) dried skim milk was stored at 37° C., the biological value went down from 87 to 66 percent after 15 days, and that the addition of lysine (1.25 percent) corrected the value back to the control level. And, finally, a quote from Patton's review of the browning process in milk products (4): "The use of non-moisture proof containers for feed-grade dry whey is a common practice that aggravates browning. Such measures may be dictated by economy. However, some studies of the nutritional merits of the browned and uncolored product would seem worthwhile. Subsequent information confirms loss of essential amino acids and the possible formation of growth inhibitors under pronounced browning of sugar-protein systems."

This should emphasize the point that no matter how promising a proposed mixture may seem, based on calculations of the individual ingredients it should contain, its ultimate value will have to be assessed, perhaps first by screening with animal studies and finally with the humans it is proposed eventually to benefit. This last would have to be both for nutritional value per se and for acceptance.

I would like to conclude my talk with some preliminary results we have just obtained by feeding weanling rats various whey products as supplements to wheat and rice. These are shown in Table 9.

TABLE 9.--Protein efficiency ratios of rice-based and wheat-based diets supplemented with milk products as determined by rat-feeding studies

Milk product added	Rice-based diet*		Wheat-based diet**	
	Percentage milk product added	Protein efficiency ratio†	Percentage milk product added	Protein efficiency ratio†
Nonfat dried milk	12.2	3.49 ± 0.08	11.5	3.03 ± 0.12
Plain dried whey	38.0	3.25 ± 0.11	35.8	2.69 ± 0.07
Dried RO whey	20.1	3.76 ± 0.16	18.9	3.31 ± 0.07

*8.5 percent protein, 50 percent from milk product.
**10 percent protein (60 percent from wheat, 40 percent from milk product).
†Grams of weight gain per gram of protein eaten.

First, we added nonfat dried milk, plain dried whey, and dried RO whey to rice in order to bring the total protein level to 8.5 percent, keeping the rice content the same. To accomplish this, the final diets contained 52.3 percent rice plus 12.2 percent nonfat dried milk, 52.3 percent rice plus 38 percent plain dried whey, and 52.3 percent rice plus 20.1 percent RO whey. The rats were fed for 3 weeks, and their growth and food intake were measured. The protein efficiency ratios shown in Table 9 are defined as grams of weight gain per gram of protein eaten. Rice with RO whey gave the highest ratio, rice with plain dried whey the lowest. The second experiment was with wheat, and was set up similarly, except that all diets contained 10 percent protein. Again, the protein efficiency ratios gave similar results as in the rice experiment: wheat plus RO whey showed the best ratio and wheat plus plain dried whey the poorest.

Now because the protein contents of the three milk products are different, the amounts added to supplement the grains varied; that is, plain dried whey was added in the largest amount, followed by RO whey, with the least amount of nonfat dried milk added. Consequently the amounts of lactose also varied in the diets in the same direction; that is, about 25 percent in the diets containing plain dried whey, about 10 percent in those containing RO whey, and 5-6 percent in those with skim milk. The animals receiving both whey supplements had diarrhea. This was especially noticeable in the wheat diet with plain dried whey and transitory when the wheat was supplemented with RO whey. Rice with RO whey caused no diarrhea. Enlarged ceca were seen in the animals fed the wheat diet with either plain or RO whey, but not in those fed rice with RO whey.

Two points are interesting, in my opinion. First, RO whey gives better ratios than skim milk. This may be because of a slightly better amino-acid profile in the whey protein or, possibly, the higher level of lactose in that diet. Second, the absence of diarrhea and enlarged ceca in the animals given RO whey with rice, in contrast to those receiving RO whey with wheat, shows that the basal diet interacts with the supplement. This could be an important consideration in recommending supplements for people whose basic subsistence diets may vary widely.

In conclusion, I hope I have been able to give you a general idea of the nutritional characteristics of whey and some comparisons that can be made between it and other products. Also, I have tried to show, by making some assumptions, how one can calculate the hypothetical value of whey or concentrated whey as a supplement to other foods. What one cannot calculate, however, is the actual physiological response to whey as a supplement, and that is what we are beginning to do with our experiments.

Discussion

QUESTION: Isn't the higher level of sulfur amino acids in the whey protein due to cystine rather than to methionine?

DR. VAUGHAN: That's right. I showed the total sulfur figures, but actually cystine is higher in the lactoglobulin. But this, of course, can substitute for methionine, to a certain extent, provided the methyl groups are present.

QUESTION: How was the RO whey prepared?

DR. VAUGHAN: I think it was one of the earlier ones prepared by Frank McDonough. It was spray-dried, as I understand it.

QUESTION: You show a much higher protein content for the RO whey than for the dried whey. What is the reason for this?

DR. VAUGHAN: The dried whey is the original spray-dried whey with no treatment by reverse osmosis or any other. The RO whey projections that I have shown are perhaps goals that one would like to achieve in concentrating the whey proteins. This reverse osmosis whey concentrate contains 50 percent lactose and about 20 percent protein. The goal is to remove enough lactose and salts to get the protein content up to 35 percent, equivalent to nonfat dried milk.

[An extended comment on lactose intolerance and on the nutritional value of whey was summarized and replied to as follows:]

DR. VAUGHAN: The point was made that first of all, some African tribes are tolerant to lactose, particularly cattle-raising tribes, and this is, of course, true. The second point was that lactose has been shown to improve utilization of calcium, magnesium, and phosphorus. In answer to that comment I would say that the experiments I showed are simply preliminary results which we just completed very recently. Calcium utilization is one of the things we are studying in these animals. And, of course, the other interesting point is that in spite of some diarrhea in these rats, they were able to utilize the reverse-osmosis whey very efficiently.

QUESTION: How about the effect of protein denaturation in the spray-drying of reverse-osmosis whey?

DR. VAUGHAN: We have not done any work on that. I would say that if denaturing lowers the biological efficiency of the protein, then we are interested in it, but, of course, as you see, it did not do that.

DR. WEBB: We haven't done enough work, really, to tell for sure, but on some of the batches we have made by RO and dried, the protein hasn't been in as good shape as it was before we dried it. Apparently there was some denaturation. You must concentrate before you dry.

DR. WOLFF: Dr. Webb or Mr. McDonough, do you have any information to give us on the particular RO whey that Dr. Vaughan used?

MR. McDONOUGH: This particular batch was made almost a year ago from cottage cheese whey. We used the Haven type 215 membrane which does allow the passage of lactose, but we didn't carry the fractionation to the point that I showed yesterday where we removed 90 percent of the volume as permeate. We stopped a little short of that. That's why we had only about 21 percent protein. Now that we go further, we can increase that to 35 percent. But the whey had a solids content of about 18 percent when it came from the unit and we concentrated it in a single pass with a falling-film evaporator. That took it up to about 60 percent solids, even though the temperature was held to about as low as the unit would work (about 150° F.). Then it was spray-dried within an hour. It is a very nice free-flowing powder, even after several months of storage. We've kept it in a polyethylene bag.

QUESTION: Did you do the RO fractionation in a single pass?

MR. McDONOUGH: No, we didn't have enough modules for that, so we recirculated it.

QUESTION: Dr. Vaughan, has much work been done on the lactose intolerance of different populations?

DR. VAUGHAN: Bayless has done quite a bit of work, as well as others I can't name offhand. In this country at Johns Hopkins, Bayless and Graham have done some work on school children. Also, there was a study published in the last year on the lactose intolerance in Thai marines which seemed to be about 90 percent. These were men in their twenties. I believe the studies on Indians were primarily on South American Indians--from Peru. There was also some work done on East Indians (as opposed to American Indians), but I can't give you the source. As to East Indians, it depends on which population you are talking about. Some are intolerant and some are not intolerant, possibly caused by hundreds of years of nonconsumption of milk. This may have occurred because of a diet difference and is now locked into a genetic difference. But there has been very little success in adapting people to lactose once they are lactose intolerant, as far as I know.

QUESTION: What was used to test for lactose intolerance, whole milk, dry milk powder, or what?

DR. VAUGHAN: For milk intolerance, usually a low dose of lactose is given.

DR. SENTI: The group may be interested that we are following up further this matter of lactose intolerance. Our Human Nutrition Division has a contract project in which we are looking in detail at black school children as compared with white. We are testing a number of school children who don't accept milk to see if lactose intolerance is responsible. Then we will see if those who do accept milk have any lactose intolerance. Both black and white children will be tested and compared. Of course, this is of importance to the Department's School Lunch and Milk Distribution Programs.

QUESTION: Are you using whole milk for this experiment?

DR SENTI: Well, the acceptance of milk will be determined with whole milk. Then for lactose intolerance, as Dr. Vaughan has said, lactose loads of varying amounts will be used, followed by determinations of blood sugar levels and other clinical differences.

QUESTION: Is whey, used as a food ingredient, taken in large enough amounts to be rejected by lactose-intolerant people?

DR. SENTI: Generally, the level of lactose in a product such as a cookie or cake containing whey would be relatively low, just as nonfat dry milk is only a small part of the CSM we distribute abroad. In giving out over a billion and a half pounds we have had no difficulty at all. But the lactose content in that case is very small. In the case of whey, where the lactose goes up relative to the protein, there may be more of a problem.

Literature Cited

(1) Henry, K. M., and Kon, S. K.

1952. The biological value of the proteins (nitrogen) of dried skim milk: effects of the addition of certain amino acids, of age of rat and of level of protein intake. J. Dairy Res. 19: 216-224.

(2) Hodson, A. Z.

1954. Nutritive value of milk proteins. II. Stability during sterilization of evaporated milk as determined by the rat growth method. Food Res. 19: 224-230.

(3) Kraft, R. A., and Morgan, A. F.

1951. The effect of heat treatment on the nutritive value of milk proteins. IV.The biological value of unheated and autoclaved dried skim milk. J. Nutrition 45: 567-581.

(4) Patton, S.

1955. Browning and associated changes in milk and its products: a review. J. Dairy Sci. 38: 457-478.

(5) Riggs, L. K., Beaty, A., and Mallon, B.

1955. Nutritive value of whey powder protein. J. Agr. Food Chem. 3: 333-337.

CHEMICAL PROBLEMS OF WHEY UTILIZATION

M. J. Pallansch
Eastern Utilization Research and Development Division
Agricultural Research Service, USDA
Washington, D. C.

When confronted with the problem of utilization of cheese whey, the chemist is immediately struck by the fact that approximately 93 to 94 percent of this material is water. At present, the water is removed by converting it to the vapor phase. The dehydration of whey solids then becomes a problem of heat and mass transfer which can best be achieved by use of either roller or spray-drying equipment (10). Neither is particularly efficient and part of the water is usually removed by boiling under a vacuum prior to the final drying step. With the best of equipment, operating under ideal conditions, at least 3 to 3.5 cents must be spent to vaporize approximately 15 pounds of the water in whey to recover 1 pound of whey solids. This is relatively expensive when considered from a thermodynamic viewpoint and improved or new methods for removing water from whey are being continually sought.

If water is to be recovered during the dehydration of whey by use of present commercial techniques, it can probably best be done during the condensing step. This can be considered a form of vacuum distillation and proper condensing equipment attached to the evaporator will make water recovery possible. Completely unanswered, at present, are questions pertaining to the chemical composition, and to the biological oxygen demand of the condensates obtainable from various types of evaporators operating under a variety of conditions. It is obvious that this is an area for research whose significance can only be considered in the long term. Of more direct and immediate interest is the use of the components of whey solids either in the mixed or the isolated form.

A cursory analysis of whey solids shows them to consist of approximately 74% lactose, 13% protein, 8% ash, 3% lactic acid, and 1% fat plus small quantities of vitamins. The lactose is usually measured in terms of the metal reducing capacity of the solids. Protein values are ordinarily derived by multiplying the nitrogen content by a factor 6.38. Both of these procedures have some shortcomings. Nevertheless, from analyses of these types, it is apparent that although cheese whey can be said to have half the solids of milk, the cheesemaking process leaves little in the whey except large quantities of lactose and a moderate amount of protein. Whey utilization must then involve capitalizing on whatever unique properties these chemicals possess.

It is surprising that lactose has been isolated from cheese whey for use and study for more than 300 years. Consequently, a voluminous literature on this subject exists. These writings have been recently reviewed (18). From this prior work, facts germane to the production and use of lactose can be drawn.

In simple chemical terms, lactose is a disaccharide formed by linking two six-carbon-containing sugars together. These constituent hexoses are glucose and galactose, and splitting the beta linkage between them will release the two sugars in the monosaccharide form. Methods capable of splitting lactose into galactose and glucose are of considerable research interest since it has been demonstrated quite recently that many people cannot digest lactose. Their bodies are apparently incapable of hydrolyzing this sugar (23).

The glucose and galactose in the lactose molecule are so joined that the double bonded oxygen group of the glucose molecule it contains is free to carry on reducing reactions. The reduction of the cupric ion by this group in lactose is the basis of a quantitative test for this sugar (1).

The carbon of glucose involved in the hemi-acetal linkage giving rise to the carbonyl-type reducing group can have either one of two possible geometric configurations. These configurations give rise to the compounds known as α- and β-lactose. The compounds differ in their physical properties and the α-form can be easily identified by its high specific rotation. References to the chemical structural studies of lactose and its physical properties can be found in a number of reviews (4, 25). Most important is the fact that the two forms of lactose have markedly different solubilities and exist in cheese whey in an equilibrium situation only slightly sensitive to changes in temperature and not at all to changes in pH and salt concentration (7). At 20° C. we can expect to find the concentration ratio of β/α in whey to be 62.7/37.3 or 1.68. From this we see that whey contains almost twice as much β-lactose as α-lactose. This ratio simply reflects the greater solubility of the β-form.

As water is removed from whey, a point is reached where the solubility limit of α-lactose is exceeded and the α-form precipitates out of solution, usually in the form of the monohydrate. Crystallization necessitates the conversion of β-lactose to the α-form to maintain equilibrium requirements. The rate at which this mutarotation occurs depends upon the temperature and pH of the system. Acid conditions and high temperatures increase the rate of mutarotation. Whether the rate of crystal growth or mutarotation is the limiting factor in lactose crystallization is still a subject of debate and research (9, 14, 24). Also to be considered is the fact that lactose crystal growth can be seriously impeded by various materials in the mother liquor (16).

The monohydrate of α-lactose is a commercially desirable product since it is relatively nonhygroscopic and therefore can be handled without caking or loss of free flow properties. Even though a moderate-sized industry is based on obtaining this material from whey by use of classical evaporation and crystallization techniques, new methods for isolating lactose from whey in less costly fashion are needed to extend the use of this material. Furthermore, the development of commercially feasible methods for the production of β-lactose and anhydrous α-forms may develop new markets for the principal solid chemicals found in whey.

When wheys are dried rapidly, insufficient time is available for the crystallization of lactose, and it appears in whey powder in the form of a glass. This is a very hygroscopic form of lactose and its presence makes whey powder difficult to handle in humid air.

The manner in which the various forms of lactose in whey powders absorb moisture from the atmosphere has been the subject of considerable research in our Dairy Products Laboratory (3). From the sorption isotherms obtained it is easy to see that at low relative humidity, lactose glass absorbs little water relative to the proteins but, as the relative humidity increases and approaches 50%, rapid water sorption by the lactose glass occurs. At approximately 50% relative humidity, the viscosity of the glass becomes low enough to allow crystallization of the lactose in the α-monohydrate form. The excess water present after crystallization vaporizes and the residual moisture is bound primarily by the salts and proteins at this and all higher relative humidities.

The conversion of lactose glass to the crystalline α-monohydrate form in powders of high moisture content forms the basis for the presently used methods of producing nonhygroscopic whey powders. Since this operation requires specialized equipment, we have been attempting to develop a simple method for the crystallization of lactose in whey concentrates prior to drying. By concentrating whey to total solids contents in excess of 65% and utilizing mechanical stirring, cooling, and seeding of the concentrate prior to foam-spray drying, we have been able to produce whey powders having approximately 70% of the lactose present in the nonhygroscopic crystalline form (2).

Regardless of the physical form in which we find lactose, its ability to enter into chemical reactions is limited to the reactive groups it contains. It can best be considered as a polyhydroxy compound containing a hemi-acetal group having potential carbonyl function. As a sugar it elicits a "sweet" flavor response from the human consumer but much less effectively than sucrose and a number of other sugars (20). Actually the sweetening power of lactose can be increased by hydrolyzing it to glucose and galactose.

The ability of the aldehydic group of lactose to condense with the free amino groups of proteins, peptides, and amino acids to produce a wide variety of flavorful and colored compounds under the influence of heat makes it a valuable component in cooked foods. This "browning reaction" has been the subject of numerous fundamental and practical studies that have been reviewed systematically on numerous occasions (21, 22).

Research carried out in DPL has identified forty compounds arising from the nonenzymatic browning of a mixture of lactose and casein. Half of these are furans and lactones easily accounted for on the basis of a Maillard type interaction (5). By investigating the optical properties of lactose-casein solutions during the course of heating, it was found that long before the appearance of visible color in the solutions, compounds were being produced that exhibited fluorescent properties. One group of these compounds was activated by light of 330 mμ wavelength, the other by light having a wavelength of 390 mμ. Both fluoresced in the visible region. As a brown color developed in the system, the amount of fluorescent material activated by the shorter wavelength light decreased while those compounds activated by 390 mμ wavelength light increased (13). This fluorescence effect is a relatively sensitive indicator of the extent of the "browning reaction" in lactose-protein mixtures occurring long before changes in color can be detected.

After lactose, the next most important whey fraction is the protein. Since these proteins are available in quantity and are relatively simple to isolate, they have been studied in great detail and excellent reviews on this subject exist (17).

Of principal interest in whey utilization is the fact that the protein fraction of this material can be almost fully accounted for by the presence of four distinct proteins. These are β-lactoglobulin (57.5%), α-lactalbumin (20.9%), immune globulins (15.1%), and bovine serum albumin (6.5%). These are all relatively low molecular weight proteins soluble at their isoelectric points when in the undenatured form. This characteristic makes them of particular interest to food manufacturers who wish to increase the protein content of acid beverages.

The resistance of the individual whey proteins to heat varies. The most heat stable protein is β-lactoglobulin. Most sensitive to heat is serum albumin. An excellent study of the relative heat stability of whey proteins at the pH of milk has been made by Larson and Rolleri (15).

During our studies of whey utilization we were surprised to find that the proteins in cottage cheese whey are much more resistant to heat than those in sweet whey. This was found to be due to the pH of the medium in which the proteins were heated. Continuing this study, we also found that as the cottage cheese whey was concentrated, the proteins achieved greatest stability in concentrates containing approximately 20% total solids (8).

The rates of whey protein denaturation in media of varying ionic strength and pH are of considerable interest to the food processor. While undenatured material is generally sought, many cottage cheese manufacturers now attempt to deliberately denature the whey proteins and precipitate them along with the casein curd. This, of course, produces a cottage cheese whey very low in protein, and determining protein by multiplying the Kjeldahl nitrogen value by the factor 6.38 will lead to serious errors.

The removal of whey proteins from solution by heat denaturation, followed by isoelectric precipitation, is sometimes used for their recovery on a commercial scale, particularly as part of a lactose manufacturing procedure. However, those denatured materials are relatively insoluble and of limited use. A specific precipitating agent which would allow recovery of whey proteins in an undenatured form has therefore been the object of considerable research.

In our laboratory we have used weak solutions of trichloroacetic acid to isolate pure, undenatured β-lactoglobulin from whey (6). This does not seem promising for the isolation of food grade whey proteins but other precipitating agents are available or will be found. We have used Hartman's observation that polyphosphates will precipitate whey proteins at acid pH in an undenatured form (11) to develop a procedure for the large-scale isolation of proteins from cheese whey. The details of this procedure will be discussed by other speakers. However, it is worth noting at this point that hexametaphosphate precipitates all but the immune globulins and that the recovered proteins contain 8.46 grams lysine per 100 grams powder. Approximately 78% of this essential amino acid is in the "available" form as determined by chemical analysis.

Those investigators interested in developing businesses based on isolated whey proteins often are concerned with the unique properties these proteins will afford prospective buyers in the food manufacturing field. Beyond their excellent solubility and nutritional values, other desired characteristics are being sought. A considerable amount has been said about the excellent foaming properties of whey protein solutions but few hard data are available about these interfacial effects.

Since highly surface active proteins are excellent emulsifying agents, we systematically investigated the interfacial activity of the various whey proteins in model systems consisting of butteroil and water or whey. In oil-water systems, α-lactalbumin and bovine serum albumin can depress the interface tension markedly and are almost equivalent to the membrane protein normally present on the fat globule surface. In whey-butteroil systems, bovine serum albumin is a much less effective interface energy depressant and the pseudo-globulins become most effective, followed closely by α-lactalbumin and β-lactoglobulin (12). From this we can conclude that the whey proteins can act as excellent emulsifiers in fat-containing systems. Some preliminary work carried out by our group indicates that a large percentage of the proteins in whey can be isolated from the aqueous phase by homogenizing food grade oils into whey and centrifuging out the cream. Easy recovery of the whey proteins from the fat globule surfaces still remains a problem.

In concluding a discussion of whey constituents, it must be said that little published information exists about the salts, vitamins, and trace constituents found in cheese wheys. The salt system of milk has undergone considerable investigation (19) and some of the data may be roughly extrapolated to cheese whey. However, when considering the variety of milks and methods used in cheese manufacture, more analytical studies must be made before the composition of the salt fraction of whey can be defined. At present, a consideration of this fraction only in terms of the calcium, sodium, potassium, phosphate, and citrate known to be therein makes the problem of its ultimate economic utilization seemingly difficult.

Along with the need for more precise analytical data pertaining to cheese whey composition, more research is needed in many areas to make full utilization of whey possible. Some of the problem areas are listed below.

(1) Splitting of lactose by enzymatic or chemical methods.

(2) Lactose mutarotation rate control.

(3) Lactose crystallization rate control.

(4) Lactose solvation.

(5) Improved methods for analysis of lactose content and physical form.

(6) Selective precipitants for whey proteins.

(7) Whey protein hydration.

(8) Viscosity control of whey protein solutions.

(9) Formation and heat setting of whey protein films.

(10) Influence of processing on available lysine in whey proteins.

(11) Composition and size of the nonprotein nitrogen fraction of whey.

(12) Identification and quantification of phosphorylated compounds in whey.

(13) Activity of the water in whey concentrates.

(14) Selective salt extraction from whey.

(15) Vitamin content of whey.

When considering this partial list of areas in which more research is needed for whey utilization, it may be surprising that a comparatively good-sized fraction of this material is now being used for food and feed. However, a fair statement of fact may be that further rapid increase in the use of whey seems unlikely until some more information about the chemistry of whey and its constituents comes out of dairy research laboratories.

Discussion

QUESTION: Is this lactose intolerance we are talking about or is this something to do with the galactose?

DR. PALLANSCH: I'm not a physiologist, but it is my understanding that the lack of lactase in the human body prevents the lactose from being split and utilized. The result is that the body excretes the lactose in the unhydrolyzed form.

QUESTION: Doesn't the enzymatic action overcome this?

DR. PALLANSCH: The enzymatic action should overcome this, yes.

QUESTION: At what temperature do you first notice the browning effect?

DR. PALLANSCH: We haven't studied the whey proteins, but we have studied sodium caseinate which should act much the same. After 5 minutes of heating at 98.6°F., there was detectable change in a 1-percent solution.

Literature Cited

(1) Association of Official Agricultural Chemists, Official Methods of Analysis. 10th Ed., page 50. P. O. Box 540, Benjamin Franklin Station, Washington, D. C. 20044. 1965.

(2) Becker, D. L., Holsinger, V. H., and Pallansch, M. J.

1969. Manufacture and properties of high solids Cottage cheese whey concentrates. J. Dairy Sci. 52: 901.

(3) Berlin, E., Anderson, B. A., and Pallansch, M. J.

1968. Water vapor sorption properties of various dried milks and wheys. J. Dairy Sci. 51: 1339-1344.

(4) Clamp, J. R., Hough, L,, Hickson, J. L., and Whistler, R. L.

1961. Lactose. In Wolfrom, M. L., and Tyson, R. S., ed., Advances in Carbohydrate Chemistry. V. 16, pp. 159-206. Academic Press Inc., N.Y.

(5) Ferretti, Aldo, Flanagan, V. P., and Ruth, J. M.

1970. Nonenzymatic browning in a lactose-casein model system. J. Agr. Food Chem. 18: 13-18.

(6) Fox, K. K., Holsinger, V. H., Posati, L. P., and Pallansch, M. J.

1967. Separation of β-lactoglobulin from other milk serum proteins by trichloroacetic acid. J. Dairy Sci. 50: 1363-1367.

(7) Gillis, J.

1920. Nouvelles recherches sur le sucre de lait. Recueil des Travaux Chimiques des Pays-Bas 39: 88-125.

(8) Guy, E. J., Vettel, H. E., and Pallansch, M. J.

1967. Denaturation of Cottage cheese whey proteins by heat. J. Dairy Sci. 50: 828-832.

(9) Haase, G., and Nickerson, T. A.

1966. Kinetic reactions of alpha and beta lactose. I. Mutarotation. J. Dairy Sci. 49: 127-132.

(10) Hall, C. W., and Hedrick, T. I.

1966. Drying Milk and Milk Products. Avi Publishing Company, Inc., Westport, Conn.

(11) Hartman, G. H., Jr.

1966. Heat treatment of mixtures of β-lactoglobulin and κ-casein. Ph.D. thesis. University of Wisconsin.

(12) Jackson, R. H., and Pallansch, M. J.

1961. Influence of milk proteins on interfacial tension between butteroil and various aqueous phases. J. Agr. Food Chem. 9: 424-427.

(13) Kliman, P. G., and Pallansch, M. J.

1962. Some optical properties of casein-lactose interaction products. J. Dairy Sci. 45: 651.

(14) Kreveld, A. van, and Michaels, A. S.

1965. Measurement of crystal growth of α-lactose. J. Dairy Sci. 48: 259-265.

(15) Larson, B. L., and Rolleri, G. D.

1955. Heat denaturation of the specific serum proteins in milk. J. Dairy Sci. 38: 351-360.

(16) Michaels, A. S., and Kreveld, A. van.

1966. Influences of additives on growth rates in lactose crystals. Netherlands Milk and Dairy J. 20: 163-181.

(17) McKenzie, H. A.

1967. Milk proteins. In Anfinsen, C. B., Jr., Anson, M. L., Edsall, J. T., and Richards, F. M., ed., Advances in Protein Chemistry, Vol. 22, pp. 55-234. Academic Press, New York.

(18) Nickerson, T. A.

1965. Lactose. In Webb, B. H., and Johnson, A. H., eds., Fundamentals of Dairy Chemistry, Ch. 6, pp. 224-260. Avi Publishing Co., Inc., Westport, Conn.

(19) Pyne, G. T.

1962. Reviews on the progress of dairy science. Some aspects of the physical chemistry of the salts of milk. J. Dairy Res. 29: 101-130.

(20) Reger, J. V.

1958. A food chemist reveals new aspects of an old sugar-lactose. Cereal Sci. Today 3: 270-272.

(21) Reynolds, T. M.

1963. Chemistry of nonenzymic browning. I. The reaction between aldoses and amines. In Chichester, C. O., Mrak, E. M., and Stewart, G. F., ed., Advances in Food Research, Vol. 12, pp. 1-51. Academic Press, New York and London.

(22) Reynolds, T. M.

1965. Chemistry of nonenzymic browning. II. In Chichester, C. O., Mrak, E. M., and Stewart, G. F., ed., Advances in Food Research, Vol. 14, pp. 167-283. Academic Press, New York and London.

(23) Rosensweig, Norton S.

1969. Adult human milk intolerance and intestinal lactase deficiency. A review. J. Dairy Sci. 52: 585-587.

(24) Twieg, W. C., and Nickerson, T. A.

1968. Kinetics of lactose crystallization. J. Dairy Sci. 51: 1720-1724.

(25) Whittier, E. O.

1944. Lactose and its utilization. A review. J. Dairy Sci. 27: 505-537.

UTILIZATION OF WHEY IN FOODS AND FEEDS

B. H. Webb
Eastern Utilization Research and Development Division
Agricultural Research Service, USDA
Washington, D. C.

If we are to recover one-half to two-thirds of our whey production which is now going to waste, it will be necessary to increase the uses of whey in foods and feeds. Half of the solids of milk resides in the whey, but it is the half which is the least attractive in terms of flavor, nutrition, and adaptability to food-processing procedures. Since it has been difficult to utilize the third of national production we are now incorporating in food and feed, it will be even more difficult to satisfactorily utilize the presently wasted product. We must redouble our efforts to find constructive, profitable uses for whey and its components. We will succeed in processing all of the whey we produce, but the challenge for the 70's will be to satisfy consumer needs by putting this processed whey into foods and feeds with a return of production costs.

The first step in utilization should be a consideration of the raw material with which we are dealing. In terms of basic components, whey contains lactose, protein,and salts. Preferably, these components, as they occur in whey, would be directly incorporated into foods and feeds. The food technology we develop for the use of whey and its constituents should emphasize utilization of the complete whey product. But to broaden the market for whey solids we must consider what products can be produced by fractionating the whey into its individual components. We must avoid expensive and unusual processing steps that will impose economic burdens on the individual components and narrow their range of usefulness as food ingredients.

The chemical properties of whey and of its components impose limitations on their usage in food and feed, and these have been described by Dr. Pallansch. We must find uses where these chemical properties will be an advantage, and thus enhance values. To change chemical properties to meet special requirements may often be so costly as to render the products noncompetitive as food ingredients.

The nutritional properties of whey and of its components have been discussed by Dr. Vaughan. Suffice it to say that whey protein is of very high biological value. Lactose is unique as a carbohydrate and apparently fills special functional needs in the body. The quantities of lactose introduced into our foods may have to be limited so that certain individuals intolerant to this sugar will not be subjected to undesirable symptoms. Lactose hydrolysis is one means that might be used to overcome lactose intolerance.

The salts and vitamins of whey are usually not considered to be of great nutritional significance, at least not to the extent that we have succeeded in selling them as highly valuable components. Indeed, the salts of whey appear to be responsible for giving it certain undesirable flavor notes. While the flavor of whey itself is not appealing, attractive flavors can be produced when it is combined with other food components.

The secret of the successful use of whey in food and feed is to adapt the properties we have to the requirements we must meet in the products we are preparing. This must be done within the economic limitations set by competitive materials.

Preparation of Whey for Food and Feed Use

Fresh pasteurized whey as it comes from the vat is the simplest form to use for either foods or feeds. But we seldom find a food-processing operation located so that it can utilize fresh whey, including the 94 percent water which it contains. So we must prepare whey products that contain high concentrations of whey solids, that are easily transported, that will have storage stability, that will blend well into the food or feed being produced, and that are economic sources of milk solids.

Condensed whey containing 35 to 60 percent solids in which the lactose appears as very fine crystals can be used for some food manufacturing purposes. Such a concentrate may be added directly to processed cheese foods. Condensed whey paste or blocks have been popular as animal feed. Sweetened condensed whey containing 38 percent whey solids and 38 percent sugar keeps well, whips to 200 to 300 percent overrun and can be used in foods where equal weights of sucrose and whey solids are desired. A series of candy formulas has been developed utilizing sweetened condensed whey (9).

Dried whey is the most popular and the most suitable form of whey to use for either food or feed. Most of the commercial dried whey is made so that the lactose in the dried product is largely crystalline. This stabilizes the product and prevents it from picking up excessive quantities of moisture and caking. A second type of dried whey is that which is spray-dried from a whey concentrate where no lactose has been crystallized. This powder contains amorphous lactose and soluble protein, but the lactose readily picks up moisture which may cause caking of the product. A third powder can be made so that about half the lactose is crystallized before drying. This powder will absorb some moisture, but if it is made by foam-spray drying the unique spherical particles will not pack into a hard cake but will remain readily dispersible. A fourth type of dried whey is the roller dried or "popcorn" whey. This is the cheapest product but it is suitable only for animal feed.

The individual whey components are manufactured for special food uses. Lactose is produced in several different grades for food and pharmaceutical products. The crude grades contain up to about 98 1/2 percent lactose. Edible lactose should run from 99 to 99 1/2 percent lactose, while the USP sugar contains about 99.85 percent lactose. For some food and feed products where the presence of milk protein and milk salts are not objectionable, whey is the cheapest source of lactose. But for many uses, the salts and the proteins are not desirable and in such cases, the better grades of lactose should be used for the food product.

Lactose may be hydrolyzed by using a lactase enzyme preparation. Acid hydrolysis is not practical because exceptionally severe conditions are required. The products of hydrolysis, glucose and galactose, are more soluble and sweeter than lactose, and for some food uses the hydrolyzed preparation may prove to be the most acceptable. Lactase has not been commercially available except during intermittent periods when there appeared to be commercial interest in it. Interest is again increasing and several companies are considering the preparation of a commercial lactase. Hydrolysis of lactose in a whey food preparation can serve to avoid lactose crystallization, to alter body properties by substituting smaller more soluble hexoses for less soluble lactose, to increase sweetness, or to reduce the risk of lactose intolerance.

High-protein whey preparations, which we will refer to as HPW, are promising whey protein fractions for food use. HPW may vary in its protein, lactose, and ash content. This is a new product and there is no established composition. The protein is concentrated by reducing the quantities of lactose and salts by reverse osmosis, electrodialysis, or gel filtration. HPW fractions are being prepared commercially by electrodialysis and to a lesser extent by gel filtration. The composition of some of these is given in Table 1 (p.106). The products are not yet normal articles of commerce. Some of the processes are patented and the preparations are priced so that the cost of the protein is higher than that of protein in dried whey. We believe reverse osmosis (RO) will be the preferred method for preparing HPW. We have prepared a number of batches at Beltsville, and we note a commercial RO installation in Illinois was reported recently (1). At Beltsville each 10 pounds of fluid whey treated by RO produced 1 pound of HPW containing 20 percent total solids. On a solids basis 0.7 pound of whey solids was fractionated into an HPW fraction containing 0.2 pound of high-protein solids and a permeate fraction containing 0.5 pound of mixture of lactose, salts, soluble nitrogen, and other minor constituents.

We visualize RO installations which will produce HPW by the recycling of whey into a product somewhat like skim milk. In dried form we believe HPW can be produced for less than nonfat dried milk. If we consider that half of the 14 billion pounds of whey now being discarded annually were to be recycled into 700 million pounds of a skim-milk-like product of 20 percent total solids and 6.3 billion pounds of permeate containing 270 million pounds of lactose and 35 million pounds of whey salts, there would be 140 million pounds of dry HPW to utilize. In 1969 we used about 1 billion pounds of NDM. The HPW would be 13 percent of our NDM usage. If the lactose left over from the HPW production were manufactured into a commercial product, there would be three times as much lactose to find a market for as we are now producing. The lactose and salt residue (70 percent of the whey solids) might instead be concentrated by RO, vacuum-evaporated, and dried for animal feed. Its nutritive value might be improved and drying made easier by incorporation of soy or other inexpensive feed protein. If only the lactose were recovered, the residue for disposal as sewage would be largely lactose mother liquor containing 35 million pounds of whey salts with some lactose and soluble nitrogen. This residue would have a biological oxygen demand (BOD) value of about 5 percent of the original whey. Let me repeat that all of these products would be produced from a portion of the whey we are not now utilizing. The magnitude of the job ahead of us is quite apparent.

Pilot-plant quantities of HPW have recently been prepared in the Dairy Products Laboratory by McDonough and Mattingly (7). A most desirable property to preserve in this new product is that of a soluble undenatured whey protein. HPW with soluble protein should have some unique food uses other than uses that would make it competitive with nonfat dried milk. The whey protein possesses unusual foaming or whipping characteristics. It is not coagulable in the presence of acid. It is heat-coagulable but will not form a strong coagulated structure at low concentrations similar to an egg white meringue. If HPW is made so that the protein becomes insoluble during concentration and drying, then in a reconstituted aqueous mixture the protein will settle rapidly. In coagulating, whey protein absorbs and binds large amounts of water. A coagulated whey protein gel may contain 70 percent water but still appear dry and crumbly. If the gel is dehydrated, the water cannot be reincorporated. Dehydration is irreversible.

Processing easily makes the whey protein insoluble so we must learn how to keep it undenatured. One way to preserve solubility appears to be to carry out the fractionation procedures before the whey is highly concentrated. Fractionation by reverse osmosis is done in the dilute whey. The protein fraction is then concentrated by vacuum evaporation and dried. To date, we have observed some loss in protein solubility as a result of the drying operation. We believe that concentration and removal of crystallized lactose before electrodialysis will adversely affect protein solubility. From our experience with RO it appears that if the lactose and salts are removed in a dilute condition, protein solubility is protected more than if they are removed in a concentrated whey. It is quite possible that crystallization of the lactose in the concentrate affects protein solubility just as it does in frozen milk concentrate.

The highest concentrations of whey protein appear to be obtainable by gel filtration. Some of the results of this work, together with the RO work which we have done in our pilot plant, will be shown at the demonstration at Beltsville. Our gel filtration process was developed by Becker, Holsinger, and Pallansch (2) by combining the observations of Hartman and Swanson (6) on the precipitation of whey protein by phosphates with those of Pharmacia Fine Chemicals, Inc.[1/] on Sephadex gel filtration. The process consists of acidifying whey to pH 2.5 with HCl, precipitating the protein with sodium hexametaphosphate, settling the mixture in a vat, and removing the supernatant solution by centrifuge. The recovered protein precipitate is neutralized to pH 6.8 with sodium hydroxide. The mixture is now passed through a Sephadex (G25 coarse) column to recover a 4 percent soluble protein solution. This is concentrated to 25 percent solids and dried to yield a powder having as much as 80 percent protein. The composition of one of these samples is given in Table 1.

Now I will consider another high-protein product obtained by fortifying whey with vegetable protein. We will designate this product as VPW, Vegetable Protein Whey. Here again, we realize we are producing a product in imitation of skim milk, one which will be cheaper than nonfat dry milk (NDM). It will probably not be as mild in flavor as skim milk, but for many food uses any residual soy flavor may be overshadowed by the stronger flavor characteristic of the food in which it is used. In looking at the dairy industry as a whole, we are not very happy about these products which may affect the market for

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[1/] Private communication (1969) from Pharmacia Fine Chemicals, Inc., Piscataway, N. J. 08854.

TABLE 1.--Composition of HPW samples prepared by reverse osmosis, electrodialysis, and gel filtration

Component	Reverse osmosis[1]	Electrodialysis[2]			Gel filtration[3]
		E1	E2	E3	
Protein	35.0	29.3	25.5	34.0	77.1
Lactose	51.4	49.6	43.3	61.5	2.9
Lactic acid	2.9	--	--	--	--
Ash	4.3	10.3	19.5	2.2	13.5
Fat	2.2	4.2	2.8	--	--
Moisture	4.0	4.6	6.0	2.8	1.9
	99.8	98.0	97.1	100.5	95.4

[1] Unpublished results obtained in 1970 by F. E. McDonough and W. A. Mattingly at the Dairy Products Laboratory, Eastern Utilization Research and Development Division, Agricultural Research Service, USDA

[2] E1, E2, E3 are commercial samples from which some lactose has been separated and salts have been removed by electrodialysis. E3 is a new product that will be available this year.

[3] Unpublished results obtained in 1970 by D. L. Becker, V. H. Holsinger, and M. J. Pallansch at the Dairy Products Laboratory, Eastern Utilization Research and Development Division, Agricultural Research Service, USDA.

skim milk. However, we believe they will assist us in utilizing surplus whey and will produce a highly nutritious product. In searching for uses for whey in food manufacture, we should emphasize those which will not conflict with the established uses of skim milk and NDM. This may not always be possible, and the decision as to whether NDM or HPW or VPW will be used will often be an economic one.

Soy is perhaps the best protein supplement for a vegetable protein whey. Such a product was described by Guy, Vettel and Pallansch of the Dairy Products Laboratory in 1969 (4) and was designed for foreign feeding programs. This whey-soy mixture was made with full-fat soy flour and fluid whey which was homogenized and concentrated under vacuum to 45 percent solids before spray drying. Evaporation of the water contained in the whey not only concentrated the fluid mixture, but removed much of the objectionable soy flavor. The whey-soy mixture reconstituted in water yielded a sweet product with the flavor of cereal and milk. It easily lent itself to artificial flavoring. The dried product showed good storage life and resisted oxidative change. It contained:

	Percent
Protein	23
Lactose	49
Fat	8.7
Ash	6.5
Soy flour carbohydrates	9
Moisture	3.2
	99.4

Where protein fortification without fat is desired, a fat-free soy flour should be used. Storage stability is better if the soy fat is not included in the formulation. Several variations of this type of product have recently come on the market for use in bakery, confectionary, and frozen dessert products. The protein content of such a VPW mixture may vary between 27 and 36 percent. Much better dispersibility and flavor is obtained if the soy flour is mixed with the fluid whey and the mixture is concentrated and dried than if a dry blend is produced. If VPW is prepared properly, the flavors usually expected from the whey and from the soy do not carry through into the finished product. Other mixtures such as sterilized whey and soy, and chocolate-flavored 2:1 beverage concentrate have been prepared (3).

Usefulness of Whey for Food Manufacture

Whey can make valuable contributions in food processing. Lactose, the dominant component, is responsible for most of the flavor intensification observed when whey or lactose is added to many food formulas.

The high lactose content seems to enhance flavor in somewhat the same manner that monosodium glutamate contributes to food flavor. There is also an improvement in the physical attribute of flavor in the creation of a pleasant "mouth feel."

Whey acts as a tenderizer in those foods where a soft or tender structure is desired. This is in contrast to the firm adhesiveness of skim-milk-containing products which are lower in lactose and higher in protein. The tenderizing properties of whey are especially noticeable in the mild brittleness of cookies, the cake-like texture of baked goods, and the delicate gel structure which may be obtained in starch pudding mixes. As in cookies, whey produces a tender crispness in pie or pizza crust. In many products whey helps retain moisture and freshness because of its high lactose content and because the lactose may often be present in the food in an amorphous condition.

The color produced in foods containing whey is an attractive golden brown developed during heating in the presence of lactose and the nitrogenous components of whey. This color is especially sought after in the crust of bread, rolls, and cake as well as on the surface of breaded meat, fish, and similar items that contain whey in the batter mix with which they may be covered.

Lactose, more often as a pure sugar rather than a component of dried whey, is used extensively as a carrier or extender in pharmaceuticals, such as pills, or in flavor concentrates. For this purpose lactose itself is practically tasteless, colorless, and stable. It absorbs pigment and supplements natural flavors.

Since the protein of whey is not coagulated at high acidity, whey may be used to make fruit-flavored dairy products. Whey will improve the body and flavor of sherbets (8), jams, fruit drinks, tomato beverages,or tomato soup. Whey can contribute whipping properties which will permit the incorporation of air on whipping of food mixes, particularly a whey-sugar mixture. Fat-free sweetened condensed whey, when whipped, will be stable for 8 or 10 hours. Some examples of foods in which whey may be utilized are shown in Table 2.

Whey with the addition of a small quantity of gelatin has been advocated as a new kind of flow agent that has the capacity to hold twice its own weight in oils, fats, flavors and other non-aqueous mixtures while the mixture still remains free-flowing. This new flow agent is made possible by adapting foam-spray drying principles (5). Air is injected into the whey before it is sprayed, and this expands the product up to 8 times the volume of normal dried whey, thus providing a greatly expanded surface area to which fats, oils, and flavors can cling. This low-density, highly aerated carrying agent is advocated for a variety of food applications in dry mixtures, especially those containing large quantities of oil or shortening.

The salt component of whey is of itself a questionable asset in food manufacture. For most of our present uses of whey components, as in concentrated protein or lactose preparations, we remove and discard some of the salts. Residues high in salts, water-soluble vitamins, and nonprotein nitrogen result from most fractionation procedures. While we have not developed a technology to produce a milk-salt product from whey, it may be prudent to look at this possibility, at least for animal feed uses. If we do not recover this material, we will be faced with its disposal.

Much more research is needed to find new food uses for whey. With an understanding of the properties of whey components we must take a new look at convenience foods to see where lactose, whey protein, and whey salts, either together or separately, can make worthwhile contributions.

Whey as a Component of Animal Feed

Long before whey was utilized in human food, it was fed as a fluid to hogs, poultry, and other farm livestock. Large pig farms where an important component of feed is fluid whey from nearby cheese factories are still flourishing in parts of Europe and Australia. This primitive procedure for handling whey as a swine feed has been an effective means of disposal, but modern animal feed compounders now use whey in dry form to much greater advantage. There are calf and pig starters and boosters; dairy cow grain mixes; dry, pelleted, or block poultry feeds; horse feeds; sheep pellets; whey-containing pet foods; and special blends for other animals. The amount of whey solids used in these feeds varies from 1 1/2 to 5 percent on a dry feed basis. In 1967, about 26 million tons of commercial feeds were produced in the United States. It would take a

TABLE 2.--Examples of the utilization of whey in foods

Food	Quantity of whey solids (percent)	Outstanding contributions of whey components besides low cost and good nutrition
Baked goods--sweet goods, bread, crackers (percent of flour weight)	3.0	Flavor, texture, shorter dough time, improved keeping quality.
Dry mixes	10.0	Tenderizing, color, flavor.
Dry whey flow agent to absorb oils	93.0	Carrier for fats, oils.
Ice cream Sherbet	2.7 4.0	Flavor, acid and fruit stability
Confections (8) Icings, frostings Jams, apple butter	10.0 6.0 4.0	Flavor, body, moisture retention, whipping properties.
Water ice on a stick	2.6	Furnish Ca, P, lactic acid, retard tooth erosion.
Batter mix (for frying)	5.0	Color, flavor.
Whey-soy beverage, citrus flavor	6.0	Lactic acid (from cottage cheese whey), flavor.
Whey-soy beverage, sterilized (35 percent total solids)	16.5	Flavor, body.
Process cheese	10.0	Body and flavor.
Whey 2/3, soy 1/3, dried	66.0	Masks soy flavor.
Whey-soy blends for food manufacture (use fat-free soy flour	40.0	Masks soy flavor, high protein.

third of our national whey production to fortify these feeds at a 1-percent level. All of our whey solids could be used in feeds if whey prices were below production costs.

Condensed whey is used as a semisolid block, especially for poultry and pigs. To produce it, fluid pasteurized whey may or may not be fermented by a special starter to increase its acidity and decrease its lactose. It may then be concentrated under vacuum to 40 to 60 percent solids and flowed from the vacuum pan into lined cartons containing 25 or 50 pounds of concentrate. Vitamins and other essential nutritional elements may be added to the mixture. As the whey cools in the container, lactose crystallization becomes complete and the product sets up as a gel which can be fed directly. The feed value of whey may be increased by inoculating the liquid whey with a culture of *S. fragilis*. This will delactose the whey and essentially replace part of the lactose with yeast cells. The yeast may be removed for feed or the whole mixture dried.

So-called "popcorn" whey may be made on a roller dryer by coating the rolls with either fluid or partly condensed whey. Care must be used in roller drying to avoid producing a product of dark color. The price roller powder brings as feed barely recovers processing costs.

Spray-dried whey or whey fractions are the best whey preparations for animal feed. Whey is either concentrated and spray-dried or part of the lactose is removed for lactose production. The mother liquor from the lactose operation, which may contain half the lactose of the whey, is dried to produce an animal feed.

The return to the manufacturer for animal feed is barely enough to cover the cost of processing. This situation has provided added incentive to whey handlers to upgrade whey as animal feed, hence the various specialized whey products which are produced. As the livestock industry increasingly uses pelleted feed, whey has been found to be an excellent pellet binder. It reduces the fines and increases feed-mill production rates. Steam may be used with the dried whey to get an effect similar to that obtained in agglomerating NDM and to cement the pellets tightly together.

We must continue to explore the animal feed market. Probably 60 to 70 percent of the whey we are now selling is going into feed. This situation may continue through the 70's but for the benefit of the cheese manufacturer and the whey processor, we hope food uses will outstrip whey feed production in volumes of whey utilized.

Literature Cited

(1) Anonymous.

1970. Reverse osmosis separates solids from whey for 1¢/lb. Food Proc. 31 (1): 26-27.

(2) Becker, D. L., Holsinger, V. H., and Pallansch, M. J.

1970. Unpublished results from Dairy Products Laboratory, Eastern Utilization Research and Development Division, Agricultural Research Service, USDA.

(3) Edmondson, L. F., Avants, J. K., and Douglas, F. W., Jr.

1968. Utilization of whey in sterilized milk. (Abstract) [Paper presented at 63rd meeting, American Dairy Science Association.] J. Dairy Sci. 51: 931.

(4) Guy, E. J., Vettel, H. E., and Pallansch, M. J.

1969. Spray-dried cheese whey-soy flour mixtures. J. Dairy Sci. 52: 432-438.

(5) Hanrahan, F. P., and Webb, B. H.

1961. USDA develops foam-spray drying. Food Engin. 33 (8): 37.

(6) Hartman, G. H., Jr., and Swanson, A. M.

1966. Precipitation of protein from cheese whey with polyphosphates. J. Dairy Sci. 49: 697.

(7) McDonough, F. E., and Mattingly, W. A.

1970. Pilot-plant concentration of cheese whey by reverse osmosis. Food Technol. 24 (2): 88-91.

(8) Potter, F. E., and Williams, D. H.

1949. Use of whey in sherbets. Ice Cream Rev. 32 (12): 44-45; 102-104.

(9) Webb, B. H., and Hufnagel, C. F.

1940. Whey solids in candy. Food Res. 5: 185-195.

Conference Panel: Summarizing Discussion

INTRODUCTORY REMARKS

W. S. Arbuckle
Department of Dairy Science
University of Maryland
College Park, Md.

It's been my pleasure to work for the U. S. Department of Agriculture since 1956, carrying the Department's findings in what we call utilization research to industry and getting commercial adaptation of it. Among other things, we did quite a lot of work on the installation of waste-disposal plants. Some of these are still in operation, and it's a major accomplishment just to go back and be admitted after these plants have been in use so many years.

Here in Maryland we undertook a pilot study on the prevention, utilization, and control of waste. A number of waste-disposal units were installed, including activated sludge, spray irrigation, and trickling filter. As a result of a study made in one rural county, the county sanitarian was able to get all the industrial processing plants cleared with the State Department of Health and Water Resource. In this county there were two dairy plants, a poultry processing plant, a cannery, and a sawmill. This is just an example of the type of thing I've been interested in as I have worked on the utilization of dairy products and especially of whey.

About two years ago, all the dairy manufacturing extension specialists of the various States were invited to this building to be brought up to date on the waste-disposal project and also on a pilot operation that had been established in this area to process acid whey. So the key people at the agricultural institutions in each State are pretty well aware of the things we are talking about at this time. This gives a basis for operation at the local level, and we think that this is important.

Now in the work with whey utilization and waste disposal we have found that there perhaps is no set pattern for any one plant to move into this operation. It's a matter, first, of reducing waste volume; second, of determining how much there is and what its strength is; and, perhaps finally, of separating the whey into its components and utilizing what can be utilized and disposing of the rest.

As we start the panel discussion this morning, we may not be able to answer individual questions or solve individual problems because I am sure they are all different. But I am also sure that the panel will summarize and emphasize some things that have been said in a way that will be helpful.

WHAT PLANTS PRODUCING LESS THAN 100,000 POUNDS OF WHEY PER DAY MIGHT DO

B. Heinemann
Mid-America Dairymen, Inc.
Springfield, Mo.

Before discussing specific possibilities, it may be helpful to supply some background information on how whey can be utilized in plants producing less than 100,000 pounds a day. First of all, let us consider the size of these plants. Data on size distribution of American cheese plants were given in a 1966 report of the National Commission on Food Marketing. It reported data actually collected in 1961, so some allowance for changes must be made.

The figures indicated that 37 percent of the plants produced less than 11,000 pounds of whey a day, 67 percent less than 22,000 pounds, 87 percent less than 45,000 pounds, and 98 percent less than 110,000 pounds. In 1948, the average plant producing American cheese handled 11,000 pounds of whey a day, and in 1968 this figure increased to 42,000 pounds. For cottage cheese plants, these figures are 2,200 pounds of whey a day in 1948 and 14,000 pounds in 1968.

It appears, therefore, that we are talking about the large majority of cheese plants in the United States when we are considering those plants that produce less than 100,000 pounds of whey a day. Thus the problem of utilization of whey from these plants is complicated by the relatively small volume of whey which is to be handled. The trend, however, is toward larger plants. There were 1,240 cottage cheese plants in 1948, and 678 in 1968. There were 2,295 other cheese plants in 1948 and about 1,048 in 1968. This is a change in the right direction as far as whey utilization is concerned.

Because of labor costs, high-capacity equipment is desirable. Large drying plants, for example, are much more economical to operate than small plants. This outlet appears to be the most widely used in the country today. According to American Dry Milk Institute statistics, about 8 billion pounds of liquid whey was dried in 1968, about 40 percent of the total whey available.

The fixed costs for drying whey in a small plant are excessive. For example, a plant to dry 10,000 pounds of liquid whey an hour with a two-stage dryer would cost about $175,000 installed. An evaporator to condense the whey produced by a plant of this size would cost about $100,000 installed. This plant, operating 10 hours a day, 365 days a year, would produce 2.3 million pounds of dry whey a year. At 6 percent interest and 8.5 percent depreciation, the total capital cost for the dryer and evaporator amounts to $39,875 a year, corresponding to a figure of $1.75 a hundredweight for the dry whey. (The capital cost of the dryer alone runs about $1.10 a hundredweight.) This represents a healthy portion of the selling price of animal feed whey which is around $4.00 a hundredweight.

Compare this fixed cost with that of a dryer costing $325,000 and having an annual capacity of 11.6 million pounds of dry whey with a fixed capital cost of around 41 cents a hundredweight[1/].

[1/] I am indebted to Thom Simmons of C. E. Rogers Co. for some of these figures.

These figures are intended only to illustrate the need to have large-capacity equipment available to handle whey economically. Since a small cheese plant cannot operate a dryer competitively, the next approach is to transport the whey to a central location for drying. Here again costs, depending upon volume and distance, are important.

It is estimated that it costs about 35 cents a mile to haul 45,000 pounds of whey. If the truck comes back empty, the cost is 70 cents per mile of whey hauled. Stated differently, a load of whey can be shipped 64 miles to a central processing location for 10 cents per hundred pounds. If the whey is not concentrated, this 10 cents adds about 0.8 cent to the cost of a pound of Cheddar cheese produced or 0.6 cent per pound of cottage cheese. This is 1.6 and 4.2 percent, respectively, of the selling price of these two items. Hauling the whey without concentration, if not figured on the cost of cheese, will add 1.7 cents per pound to the cost of dry whey.

This cost can be reduced by concentrating the whey, but then the cost of removing the water must be considered. Concentrating whey to 40 percent solids for shipping 64 miles adds only 1/4 of a cent of freight per pound of dry whey. But 255,000 pounds of water must first be removed. The fixed capital cost of an evaporator designed for concentrating 100,000 pounds of whey a day will run about 0.6 cent per pound of dry whey. McDonough and Mattingly report that the cost of reverse osmosis is approximately $1.00 per thousand pounds of water removed, or $255 in the case of the above example. This corresponds to a cost of about 1 cent per pound of dry whey. If whey has to be hauled any distance, it probably is desirable to concentrate it in the most economical manner possible.

What, then, can the smaller cheese plant do to utilize whey and to prevent pollution?

1. The very small plants can consolidate. The National Commission on Food Marketing states plainly, "In the past small cheese factories frequently returned whey to farmers for feed or allowed it to run into streams or fields as waste. Efforts to eliminate stream pollution have caused many factories to develop other disposal methods. In some instances the best alternative for the small factory was to go out of business."

2. Spray fields with whey, thus obtaining some fertilizer benefit from it. This is safe if proper soils are selected, excessive use is avoided, and other precautions are observed.

3. Ship the whey unconcentrated. This is economically sound if the distance to a central plant is short and the volume of whey is small.

4. Install concentrating equipment and ship concentrated whey to a central plant. This is economically sound if the whey production is on the order of 40,000 pounds per day. The equipment would include evaporators or (when adequately proved) reverse osmosis concentrators.

SUMMARY OF WHEY PROCESSING PROCEDURES

K. W. Royer
Purity Products Company
Mayville, Wis.

When our good cheese friend from the world of fairy tales, Little Miss Muffet, sat on her tuffet, she was eating a delicacy of merry old England. In her day, curds and whey furnished important food elements in the diet of English peasants. At the same time, they were almost a complete meal, furnishing all the nutrients originally included in the milk. But along the way, the habit of enjoying this delicacy was lost.

Mr. V. Cheke, writing in "The Story of Cheesemaking in Britain," says that in England, "Whey was esteemed as a drink and would be bought in whey houses which were favorite meeting places or loose in the street from farmer vendors."

So it is this background which brings us to the utilization of these dairy solids in a new generation of concentrated protein products. We are basically creating extremely nutritious food products from the solids of whey which have for many years been largely discarded. The emphasis on pollution control has made it essential that our whey industry process into edible products all of the available whey rather than only one-third of it. This has put pressure on the development of systems to process the product which are as up-to-date as the new products themselves.

Whey is composed, essentially, of albumin, lactose, and ash. For many years, lactose was the prime product for a number of factories in the United States. Now it is fast becoming a byproduct, and we are seeing the importance of the albumin. If we are to concentrate the albumin, removal of the lactose is one of the essentials. Another is removal of the minerals.

We have been involved for two days in discussing the mechanics of processing whey. I do not see any need to refresh the memory of you well-informed gentlemen on the alternative processes available for condensing whey.

After the product is condensed, the project becomes one of separation or segregation of the various components. Perhaps this can be achieved at the same time as condensing by some of the reverse-osmosis type processes. This segregation is essential to the development of carefully defined high-protein products. I would like to visit with you a few minutes about a process our firm has developed, called transport depletion. It must be differentiated from classic electrodialysis to which it is similar. Transport depletion, as practiced by the Purity Products Company, employs a neutral membrane instead of the anion membrane used in the classic electrodialysis system.

Protein molecules bounce off the neutral membrane instead of clogging the pores as they do in the anion membrane. The result is that the salts and, in the case of whey solids from cottage cheese, the acids are removed, with protein remaining in the main stream.

Our stack running time for transport depletion is five to six times longer and labor is reduced since cleaning of the membranes is proportionally cut. Higher production can result from longer running time at higher current loads.

Mr. John Scheder, our production manager, says that using transport depletion to remove salts ahead of either ultrafiltration or sephadex gel results in a purer protein with a lower salt content than is possible with either of the former systems alone.

If part of the water is first removed from the whey by reverse osmosis, transport depletion will be more efficient because it will have a higher concentration of salts to work on.

Transport depletion is particularly useful for desalting whey from which lactose has been partially removed. This is the stream in which transport depletion is used in our plant. The whey then has a higher concentration of protein and a higher percentage of salts. Removal of salts by transport depletion, of course, concentrates the remaining protein even further and generates a higher value of product. One of our typical products called LP 10 has 10 percent ash, 28 percent protein, 51 percent lactose, the remainder being some fat, moisture and lactates and citrates. The pH is 7.2 on a 1:9 dilution basis. The protein is completely soluble and undenatured, and can be easily dispersed in either high- or low-moisture food systems. Obviously the whipping characteristics are excellent, and this has led to its use as the sole source of serum solids in a frozen dessert. For consumer purposes the product is labeled as modified whey. The product has also been found useful for formulations in nuggets, whipped centers, whipped toppings, and nondairy sour cream base.

The transport depletion system can desalt to any level, though it becomes less efficient as the salt content of the final product is reduced. The process is fully developed now, and is available for license from the Purity Electrochemical Company, a companion of the Purity Products Company. It is operating 24 hours a day, 7 days per week at our plant.

In conclusion, it is our desire that the system we have worked with will find its place in solving some of the major problems of our country by easing the nutritional shortage of many of our people and overcoming the pollution potential of cheese whey.

Now I would like to comment on some of the things that have been said during the last day and a half. First, although I am not an expert on nutrition, I have heard that if whey solids were in every product fed to every animal in the United States, we would have too little whey even to supply it. Now I know very well that there isn't whey in every feed product, at least in the area of Wisconsin that I live in, so we should look into this.

Second, with lactose fast becoming a byproduct of a byproduct, it seems to me it is essential that we learn how to split it, not only to avoid the lactose tolerance problem we discussed this morning, but to improve it so it can be used in more foods and even make it possible for it to compete with sucrose in the 11-cent range in order to dispose of lactose.

Third, I feel that we spent far too little time talking about how we are going to use this product. That's been the subject this morning, and we simply cannot get far enough in that short a time. I wonder if it wouldn't be a good idea to assemble a group of research directors and marketing people on whey in a seminar-type discussion on this subject. If we make all our whey into a dry powder, we are going to have to do a tremendous selling job in order to move it.

Fourth, our company has been actively soliciting consumer recognition of the value of whey in food formulations. Before I left the plant on Monday, I received from our clipping service a number of items appearing in newspapers as a result of a story we put into the United Press International circuit just a month ago. The article was designed to convince the consumer that she must not only tolerate whey in food, but that she ought to insist that it be there because it is nutritionally good and it solves pollution problems. In Tampa, Florida, the Tribune ran a story with a picture, headed, "Little Miss Muffet Knew a Good Thing." Says the Courier-Post of Camden, N. J., "Miss Muffet's Whey Now Enriches Food." The Chronicle in Allentown, Pa., headed its account, "Nutrition Lesson in Nursery Rhyme," and the News-Sentinel, of Knoxville, Tenn., wrote, "Industry to Capitalize on Miss Muffet's Diet. Helps Fight Pollution." This is an article we thought it was worth spending money on in order to help convince the consumer that she ought to help us "eat this problem."

Finally, I think it's time the whey industry recognizes that it must organize itself. This could be either a new industry group, or it could be part of the National Cheese Institute, or of the American Dry Milk Institute. I think that from these three possibilities we should make a selection so that we have a place for the exchange of views and the finding of solutions to the problem we have been talking about.

VIEW OF USES AND MARKETS FOR WHEY PRODUCTS

J. T. Hutton
Foremost Foods Company
Dublin, Calif.

Markets are a dynamic and competitive thing. They shift and change in pursuit of the changing needs of man. They are captured by those who can deliver what the consumer wants, when he wants it, and where he wants it.

Within this reference frame, I would like to examine what has been said, and some things which should have been said, about the uses and markets for whey.

In summary, I am impressed by contrasts--by contrasts between where we've been, where we're going, and why we want to get there.

I am impressed by our changing values and attitudes relating to the environment. We are here today because we have become aware that we live in a closed, delicately balanced, highly complex, inter-related, and interacting life support system. We are concerned because the life support system we are here to protect is our own.

I am impressed, too, by the contrast between what we have done and what we need to do. With no pun intended--we have come a long way and we have a long way to go.

We are utilizing about 50 percent of the Nation's whey solids. We have developed markets in the food, feed, and pharmaceutical industries. We are exploring advanced process technology. Some is already in use, and some is being pilot tested.

We have made a choice. We have decided against high taxes and high prices as the cost of environmental quality. We have chosen profit in preference to pollution.

But I question whether we have faced the problem squarely. I wonder whether we are prepared to meet the challenges that lie ahead.

I am reminded of the story of a father and his son Tommy. Tommy came home from school one day and passed his report card to his father, saying as he marched quickly to his room, "Hey, Dad, will you sign this for me?"

Dad said, "Sure," but as he looked at it he felt his lid beginning to rise. Anxious to keep the generation gap closed, he put the lid back on, and walked to his son's room.

"Tommy, how do you explain your grades?" he asked. "I see you got 4 F's and 1 D."

After a moment of silence, Tommy said, "Well, Dad, the only way I can explain it is that I over-concentrated on my favorite subject." I can't escape the feeling that we, too, have over-concentrated on our best subject--process technology.

I am also reminded of a group within our midst that can be called the silent minority. These are our marketers; these are our salesmen. Our future depends on them. They have a tremendous job to do. They deserve recognition.

I see another contrast between the past and the future. In the future, as in the past, successful business will be founded on 3 elements: products, markets, and financing. Each must be present at the same time and in proper balance. The essence of success will continue to be clearly defined markets in which identified products will sell profitably.

In relation to the past, the future will be faster paced. To those willing to march to a quickening beat, it will be dynamic, exciting, complex, and competitive.

We will move deeper into an era of automation and its side effects. We will match wits for markets, both here and abroad. We will have available to us the advantages of micro-second information processing and near-instant communication.

Products and services will tend to be pre-engineered, manufactured, and delivered to meet a broadening and changing spectrum of consumer needs.

I see a further contrast between what we know and what we need to know.

To profit in this future environment will take real know-how. Industries and their member companies will prosper or fail. Which way we go will depend on knowledge, imagination, and ability to create rather than to become a victim of change. We need to know what our markets are, where they are, and how to reach them.

More specifically, we need to know who our customers are, what their needs are, and what products we can make to fill those needs profitably.

We need to know who our competitors are, what advantages they have over us, and what advantages our raw material, our products, and our distribution systems have over them.

We must at all times know where we stand in that delicate relationship between price and value.

To do this we must add to what we know. We must know more about our raw material, its components, its derivatives, its uses.

Let's look at it this way. At this conference we have talked about markets in feeds, foods, and pharmaceuticals for about 700 million pounds of whey. These markets were developed through trial and error over a period of some 40 years. Now we need sales for a second 700 million pounds of whey in a fraction of this time.

To expect the number of babies, purchases of bread, production of animals and poultry, consumption of frozen desserts, and the need for pill fillings and coatings to double in this same time frame would be totally unrealistic. Equally unrealistic would be an expectation that our competitors would stand idly by while we reaped the harvest of this doubled market.

What, then, is the answer? May I suggest that we:

Do our homework.
Master all of our subjects.
Learn to know and manage our business--
  every element of it.
Work with and urge on our silent minority.
  Make them a part of a united majority
  whose efforts are focused on clearly
  defined and worthwhile industry, economic,
  and national goals.

Simply put, we must use our resources--all of them--effectively and efficiently.

To achieve this end, we in industry will have to learn how to work more effectively with those of you in universities and in government and, in turn, you with us. In general, we can expect best results when the resources of our government and university laboratories are focused on basic research while the energies of industry are concentrated on the development of processes, products, and markets.

In final analysis, the results of our efforts will be measured in many ways. Some of the more important will be:

1. Product knowledge. For example, we will need to know all of the useful properties of lactose and the whey proteins. We will need to know the full role of lactose in nutrition, as a raw material, as a flavor enhancer, etc. Our competitors can spin and texturize their protein. Do we need this capability, or do whey proteins have greater profit value in other applications? And let's not forget the mineral and nonprotein nitrogen fractions of whey. We must find uses for these fractions if our pollution control program is to be fully effective.

2. Full knowledge of consumer needs and the forces changing them. In short, we need the ability to constantly match consumer needs with new products--profitably.

3. Protection of markets. Our markets need protection from international competition when this competition proves contrary to our economic and social values.

4. Prompt regulatory acceptance. Whey and whey derivatives shown to be useful in standardized foods, feeds, and pharmaceuticals must be accorded prompt acceptance by regulatory agencies.

5. Prompt clearance. Additives, preservatives, and practices useful in collecting, processing, and marketing of whey products must receive prompt clearance.

In conclusion, the future will be what we commit ourselves to making it. It can be chaotic. It can be exciting and rewarding in terms of profit and a safe, clean environment.

The result will be irreversible and measured by the caliber of our efforts.

The clock is running and the situation remains unchanged since Omar Khayyam wrote: "The moving finger writes and, having writ, moves on. Nor all your piety or wit shall have it back to cancel half a line, nor all your tears wash out a word of it." We have made the choice. Let's get started.

WHERE DO WE GO FROM HERE?

B. H. Webb
Eastern Utilization Research and Development Division
Agricultural Research Service, USDA
Washington, D. C.

Discussions at this conference support predictions in three areas: (1) whey processing, (2) greater exploitation of the nutritional value of whey as a food, and (3) increased whey utilization in food and feed.

(1) Whey processing. Our technology of whey processing is in a healthy state and making good progress. Whereas at the beginning of 1970, after 40 years of effort, we were only utilizing about one-third to one-half of the whey we produce in the United States, by 1973 virtually all of it will be processed for some kind of use. Very small quantities in scattered areas may still be diverted to sewers, but none will contaminate streams. This means that all whey producers must start very soon either to process their whey, haul it to a processing plant, or provide for its treatment as sewage. Because waste disposal is expensive and without monetary return, most of our whey will be utilized.

(2) Nutritional aspects of whey utilization. Our confidence in whey as a food will be reinforced by a growing awareness of its good nutritional qualities. Continued research will show new nutritional values of whey components for human and animal food. The problem of lactose intolerance may prove less serious than many now believe it to be. Gradual increases in lactose intake will resolve the intolerance for some persons, while hydrolysis of the sugar will be used to make it suitable for the small percentage of the world population who may actually be genetically intolerant.

(3) Finding uses for whey solids. It will prove more difficult to find uses for whey than to process it. Throughout the decade of the 70's we will be searching for food, feed, or other uses for whey. We will try first to usurp the market for nonfat dry milk (NDM). This will create problems for that product, but as long as the Government supports NDM prices, whey solids will have a market at a reasonable price. But we must find more food uses for it--preferably unique uses, not NDM uses. There will be some fortification of whey solids with vegetable protein to more effectively compete with NDM. But there must be an aggressive search for bigger, better whey markets. This will be the objective of whey utilization research in the 70's. We must take a new and searching look at whey components: lactose, whey protein, and even whey salts. We should search diligently for cheaper and better ways to make lactose and whey protein preparations. We should try to find better uses for whey salts than running them down the drain. Lactose is a unique sugar. Do we know enough about it? We have been looking at it rather critically for 50 years. Perhaps we should back off and take another look from some new directions. We will develop high-protein whey concentrates containing as much highly nutritious protein as skim milk, or more. We must find new and unique uses for these protein products, not prey on the skim-milk market. Armed with new products and new uses, we will find that they will have to be sold to food processors and to the public. More effort will be required to sell the products than to research them.

The key to successful whey utilization in the 70's will be to follow an aggressive program in research and market development.

Questions for the Panel

DR. HOOVER: A Britisher approached us about a year or a year and a half ago who felt he had a very good market in animal feeds for concentrated whey in 55-gallon returnable drums. He was very happy with his situation and that's about the only profitable use of whey that hasn't been mentioned, to the best of my knowledge.

DR. WEBB: I don't know anything more than that about it. Maybe the Foremost people, who are in the whey business, do.

MR. WARD: A long time ago we used to sell whey in 55-gallon drums. We used whisky barrels.

DR. HOOVER: This was a concentrated product that was stable on the farm, and was just mixed in with the feed.

MR. WARD: It was about 55 percent solids. It was quite stable and had a low pH. It was quite popular for a long time, but I don't know of anybody who is using it now.

DR. WEISBERG: I think the export possibilities for edible dried whey should be mentioned. This is by all odds the dairy industry's least expensive byproduct. Consideration might be given to its incorporation into the corn-soy-milk or wheat-soy blends donated to needy countries by the United States and shipped under P. L. 480. Another export possibility is that food manufacturers in, say, Central America might be persuaded to purchase our edible dried whey as a nutritive ingredient for use in crackers, biscuits, bread, or pasta, or in confections. In some of these countries to the south of us dairy products are scarce and costly.

MR. BOXER: We have discussed various types of processes in the last two days, and I think a few of us are confused. We've gone ahead with Dairy Research and Development and Dairy League in the spray-drying process. As I listen to the conference, I am getting the idea that we had better make our production line a lot longer and add electrodialysis and possibly some of the other RO's that are being mentioned. We did this for three years, and as we looked over the various possibilities, we settled on spray drying as the immediate solution. We think all the sophisticated methods are great for the next 5 to 10 years, but we consider our problem now to be one of pollution. My question to the panel is: Even if we go into fractionation, don't we still have the pollution problem to be solved? We're still here, not because we are looking for ways to get rid of whey or because of our interest in marketing; as a matter of fact we have very few marketing men here. It seems to me that if we don't have an answer to the engineering problem of getting rid of whey pollution, we are still back where we started from. We are all here in Washington to find out what to do about our pollution problem. Either we are going to dry whole whey to a powder, eat it, bury it, burn it, or do something else with it. If we fractionate it, we still have a pollution problem, and, as we were reminded yesterday, Interior is still watching us. Will the panel tell us how fractionation, gel filtration, and all these other systems help us here?

MR. ROYER: It appears that a 99-percent reduction in the BOD values is going to have to satisfy us, and that that other 1 percent is going to have to be reduced in standard sewage systems. However, I do see the possibility that perhaps someone in industry might come up with a project that could gain Federal money. I haven't asked them about it, but one might be a regional experiment to generate "zero" effluent from a whey processing plant. This would be its goal. It would be a regional effort, like the one Ken Ward's company is trying to put together in Vermont. In Wisconsin, a county in certain cases would be a region. I believe it can be done, but it's going to take some money other than industrial money to support the work that will be required.

MR. WARD: I don't know where you are going to put your whey plant, but you might just as well expect that its effluent is going to meet the standards of the particular State where it's located. Some States are setting standards as low as 15 parts per million for any discharge into the stream. Others are higher, but I don't know any above 30 parts per million. Some existing plants don't meet those standards, but new ones will not be allowed to be built unless they do. As far as pollution is concerned, you can be quite sure that any new plants are going to have to meet the standard.

DR. WEBB: I think you are going in the right direction. It seems to me that the first thing you have to do is to get it dry, get it processed, do something with it. A lot of what we have been talking about are sophisticated processes that you can't now apply to a million pounds of whey. Once you dry the whey, then of course the question is: What are you going to do with the dried product? But the first thing to do is to dry it. I don't see anything else you can do at this point.

MR. BOXER: That's what we did. The Government subsidized the operation for a half-million dollars, and we put up another million and a half, and Dairy League is building a million-and-a-half-dollar plant, and we are hoping for the best. But we are going to have zero effluent because we are going to dry a whole powder. What we are going to do with it I don't know.

MR. REY: I might just mention that in a related field, FWQA is giving a grant to a pulpmill for a complete water reuse system within a plant. This is the type of thing, I think you are talking about, where all the water possible is recycled, and the solids are burned or reused.

MR. BOXER: Our engineer showed us a way to recycle our water. But we are concerned about this 5.5 million pounds of whey powder we are going to have each year from the large plant we are building. We are now in the process of marketing the whey, and we have a number of plans which we will make known to the industry. If we can't market it, then we have a negative cost factor. In this case the cheese industry is going to have to add this to the cost of its primary product, cheese.

Appendix 1

LIST OF ATTENDANTS

Mr. R. M. Ahlgren
N1 W25850 Northview Road
Waukesha, Wis. 53186

Dr. J. A. Alford
Eastern Utiliz. Res. and Dev. Div.
Agricultural Research Service, USDA
Beltsville, Md. 20705

Mr. C. Allen, Jr.
5619 62nd Avenue
Riverdale, Md. 20840

Mr. Alvin J. Alton
525 Cross Street
P. O. Box 749
Beloit, Wis. 53511

Mr. C. H. Amundson
310 Campbell Street
Madison, Wis. 53711

Mr. R. F. Anderson
110 N. Franklin
Chicago, Ill. 60606

Dr. W. S. Arbuckle
Department of Dairy Science
University of Maryland
College Park, Md. 20740

Mr. J. M. Atterbery
1710 N. Douglas Drive
Minneapolis, Minn. 55422

Mr. S. E. Barnard
The Pennsylvania State University
213 Barland Lab
University Park, Pa. 16802

Dr. J. L. Barnhart
Department of Food Science
University of Idaho
Moscow, Idaho 83843

Dr. N. D. Bayley
Director, Science and Education
Department of Agriculture
Washington, D. C. 20250

Mr. D. L. Becker
Eastern Utiliz. Res. and Dev. Div.
Agricultural Research Service, USDA
Washington, D. C. 20250

Mr. Gint Behrens
Minneapolis, Minn.

Mr. A. Bergelin
Ferryville Cheese Co., Inc.
Ferryville, Wis. 54628

Mr. D. Berks
1525 Glenwood Ave.
Minneapolis, Minn. 55405

Mr. N. N. Bernstein
330 S. Mill St.
Juneau, Wis. 53039

Mr. E. W. Bowen
1250 Broadway
New York, N. Y. 10001

Mr. S. Boxer
Dairy Research and Development Corp.
111 Broadway
New York, N. Y. 10006

Mr. D. R. Brantz
Shawano, Wis. 54166

Mr. R. Browne
5045 Wilshire Boulevard
Los Angeles, Calif. 90036

Dr. T. C. Byerly
Assistant Director, Science & Education
Department of Agriculture
Washington, D. C. 20250

Dr. P. A. Cantor
9200 E. Flair Drive
El Monte, Calif. 91734

Mr. A. W. Cater
4570 W. 77th St., Suite 306
Minneapolis, Minn. 55435

Mr. F. Cherry
Long Meadow Farms
Durham, N. C.

Mr. E. S. K. Chian
P. O. Box 5000
Hightstown, N. J. 08520

Miss Helen Churella
Ross Lab - Div. of Abbott Laboratories
625 Cleveland Ave.
Columbus, Ohio 43216

Mr. W. J. Corbett
1126 Kulburn Ave.
Rockford, Ill. 61101

Mr. Paul L. Culler
12 Clover Park Drive
Rochester, N. Y. 14618

Mr. F. R. Daul
38 Kent St.
Kent, Ill. 61044

Dr. R. Davis
Department of Dairy Science
University of Maryland
College Park, Md. 20740

Mr. S. Dean
3600 North River Road
Franklin Park, Ill. 60131

Mr. J. J. Dee
45 East Scott
Fond du Lac, Wis. 54935

Mr. B. J. Demott
Dairy Department
University of Tennessee
Knoxville, Tenn. 37916

Mr. J. Ditkofsky
Crescent Cheese
100 Stenson Boulevard
Montreal, Canada

Mr. T. E. Drohan
111 Pine St.
San Francisco, Calif. 94111

Mr. J. R. Dudley
P. O. Box 4007
Santa Barbara, Calif. 93103

Mr. P. B. Dwoskin
Economic Research Service, USDA
Washington, D. C. 20250

Mr. L. F. Edmondson
Eastern Utiliz. Res. and Dev. Div.
Agricultural Research Service, USDA
Washington, D. C. 20250

Dr. C. T. Egger
Grain Processing Corp.
Mascatine, Iowa 52761

Mr. T. A. Evans
University of Nebraska
Lincoln, Nebr. 68503

Dr. W. Eykamp
341 Vassar St.
Cambridge, Mass. 02139

Dr. R. E. Farrar
Dairy Research Inc.
20 N. Wacker Drive
Chicago, Ill. 60606

Mr. A. Ferretti
8516 Howell Road
Bethesda, Md. 20034

Mr. F. Feutz
Borden Foods Company
802 South St.
Plymouth, Wis. 53073

Dr. C. L. Fife
176 Laurel Hill Drive
So. Burlington, Vt. 05401

Mr. C. D. Frederick
115 W. Jackson
Chicago, Ill. 60604

Mr. L. Frigo
Frigo Cheese Corp.
Lean, Wis. 54139

Mr. R. C. Fulde
Campbell Institute for Food Research
100 Market St.
Camden, N. J. 08102

Mr. S. F. Gebarski
P. O. Box 278
Dundee, Ill. 60118

Mr. D. Ghormley
5045 Wilshire Boulevard
Los Angeles, Calif. 90036

Dr. A. Gollan
Hydronautics Corp.
Laurel, Md. 20810

Mr. D. Guy
Aqua-Chem Inc.
P. O. Box 421
Milwaukee, Wis. 53201

Mr. J. Hagerman
Haven Dairy Corp.
Hogan, S. D.

Mr. C. Hallstrom
9000 Plymouth Ave. N.
Minneapolis, Minn. 55427

Mr. R. E. Hargrove
Eastern Utiliz. Res. and Dev. Div.
Agricultural Research Service, USDA
Washington, D. C. 20250

Mr. R. F. Hedtke
8619 Victoria Road
Springfield, Va. 22151

Mr. B. Heinemann
Research and Products Development
Mid-America Dairymen, Inc.
P. O. Box 1837, S. S. Station
Springfield, Mo. 65805

Mr. Ted Helbig
Cudahy Company
Washington C. H., Ohio 43160

Mr. D. E. Hennigh
2538 Telegraph Ave.
Oakland, Calif. 94612

Mr. W. Hildebrandt
Branklin County Cheese Corp.
Enosburg Falls, Vt. 05450

Dr. P. D. Hoagland
Eastern Utiliz. Res. and Dev. Div.
Agricultural Research Service, USDA
Philadelphia, Pa. 19118

Mr. A. Hockhauser
2375 E. 3rd St.
Brooklyn, N. Y. 11223

Mr. B. Hoffman
DeLaval Supply Co.
Poughkeepsie, N. Y. 12602

Mr. H. Hollenbeck
Dairylea
Hastings, N. Y. 13076

Mr. T. W. Holzinger
Borden, Inc.
350 Madison Ave.
New York, N. Y. 10017

Dr. S. R. Hoover
Office of Administrator
Agricultural Research Service, USDA
Washington, D. C. 20250

Mr. I. Horrocks
P. O. Box 184
Laurel, Md. 20810

Mr. B. S. Horton
Abcor Inc.
341 Vassar St.
Cambridge, Mass. 02139

Mr. T. Horton
800 Centennial Ave.
Piscataway, N. J. 08854

Dr. J. T. Hutton
6363 Clark Ave.
Dublin, Calif. 94566

Mr. Robert S. Igoe
333 W. Logan Ave., Apt. 407
State College, Pa. 16801

Mr. Donald L. Irey
P. O. Box 310
Havre de Grace, Md. 21078

Dr. G. W. Irving, Jr.
Agricultural Research Service, USDA
Washington, D. C. 20250

Mr. R. H. Jardine
Ontario Dept. of Agriculture and Food
Milk Comm.
Parliament Bldgs., Toronto
Toronto, Ontario, Canada

Mr. T. A. Jonas
1625 Eye St., N.W., Suite 903
Washington, D. C. 20006

Mr. R. Josephson
Dept. of Food Science and Industries
University of Minnesota
St. Paul, Minn. 55101

Dr. E. B. Kalan
Eastern Utiliz. Res. and Dev. Div.
Agricultural Research Service, USDA
Philadelphia, Pa. 19118

Mr. J. Keay
Dept. of Industry, Trade and Commerce,
Agriculture, Fisheries and Food Prod.
Ottawa, Ontario, Canada

Mr. J. A. Kirk
409 Maple Ave.
DuBois, Pa. 15801

Mr. R. Kloser
P. O. Box 42165
Portland, Oreg. 97242

Mr. W. Kneeland
500 Rutherford Ave.
Boston, Mass. 02129

Mr. C. W. Kolar, Jr.
Ralston Purina Co.
835 S. 8th St.
St. Louis, Mo. 63199

Mr. E. P. Kolen
801 Waukegan Rd.
Glenview, Ill. 60025

Mr. D. C. Kolpack
Box 27
Mayville, Wis. 53050

Mr. J. H. Kraft
18 Indiana Hi - 1 Rd.
Winnetka, Ill. 60093

Mr. H. Kravitz
273 Columbus Ave.
Tuckahoe, N. Y. 10707

Mr. M. Kroger
The Pennsylvania State University
107 Borland Lab
University Park, Pa. 16802

Mr. D. E. LaCroix
2517 Corning Ave.
Oxon Hill, Md. 20021

Mr. W. J. Lacy
Federal Water Pollution Control Admin.
1921 Jefferson Davis Highway - Bldg. 2
Arlington, Va. 22202

Mr. F. A. Lasley
2203 Basset St.
Alexandria, Va. 22308

Mr. A. Lee
Northern Creamery Supply
Saratoga, N. Y. 12866

Dr. M. Loewenstein
Dairy Science Dept.
University of Georgia
Athens, Ga. 30601

Mr. A. J. Luksas
1526 S. State St.
Chicago, Ill. 60605

Mr. G. P. Lynch
Animal Husbandry Research Division
Agricultural Research Service, USDA
Beltsville, Md. 20702

Mr. P. Maggio
1100 S. 11th St.
Philadelphia, Pa. 19147

Dr. J. H. Martin
Dairy Science Dept.
University of Georgia
Athens, Ga. 30601

Mr. W. A. Mattingly
Eastern Utiliz. Res. and Dev. Div.
Agricultural Research Service, USDA
Beltsville, Md. 20705

Mr. B. M. Mayer
Knudsen Corp.
P. O. Box 2335
Terminal Annex
Los Angeles, Calif. 90054

Mr. T. G. McDermott
11 Pine St.
San Francisco, Calif. 94111

Mr. F. E. McDonough
Eastern Utiliz. Res. and Dev. Div.
Agricultural Research Service, USDA
Washington, D. C. 20250

Mr. H. J. McEvoy
145 E. 92nd St.
New York, N. Y. 10028

Mr. R. E. Meade
311 Second St., S.E.
Minneapolis, Minn. 55414

Mr. H. E. Meister
Dairy Division
Consumer and Marketing Service, USDA
Washington, D. C. 20250

Mr. R. L. Merson
510 Collidge Court
Davis, Calif. 95616

Mr. N. W. Meyer
Miles Laboratories Inc.
Marschall Division
Elkhart, Ind. 46514

Mr. R. I. Meyer
Food and Drug Administration, USDA
Washington, D. C. 20250

Mr. K. L. Miller
1000 N. 7th St.
Allentown, Pa. 18102

Mr. H. A. Moore
700 Packer Ave.
Philadelphia, Pa. 19148

Dr. H. Morris
Dept. of Food and Science
University of Minnesota
St. Paul, Minn. 55101

Mr. G. A. Much
1126 Kilburn Ave.
Rockford, Ill. 61101

Mr. P. J. Muldoon
Department of Food Science
Virginia Polytechnic Institute
Blacksburg, Va. 24061

Mr. J. Neu
Neu Cheese Company
Hartington, Nebr. 68739

Mr. A. M. Nielsen
Rugby Creamery
209 West Dewey
Rugby, N. D. 58368

Mr. V. Nielsen
P. O. Box 278
Dundee, Ill. 60118

Dr. K. M. Nilson
University of Vermont
Burlington, Vt. 05404

Mr. R. Norton
500 Rutherford Ave.
Boston, Mass. 02129

Dr. G. C. Nutting
Eastern Utiliz. Res. and Dev. Div.
Agricultural Research Service, USDA
Philadelphia, Pa. 19118

Mr. C. F. Obenauf
1526 S. State St.
Chicago, Ill. 60605

Dr. F. Osman
1100 S. 11th St.
Philadelphia, Pa. 19147

Dr. M. J. Pallansch
Eastern Utiliz. Res. and Dev. Div.
Agricultural Research Service, USDA
Washington, D. C. 20250

Mr. C. Panzer
Eastern Utiliz. Res. and Dev. Div.
Agricultural Research Service, USDA
Philadelphia, Pa. 19118

Mr. O. W. Parks
6802 Nashville Rd.
Lanham, Md. 20801

Mr. D. Pauly
908 E. Birch St.
Manitowoc, Wis. 54220

Dr. Francizih Pedgiwich
Poznan, Poland

Mr. A. S. Penfold
Jessup Coop Creamery
Jessup, Iowa 50648

Mr. W. R. Redelmeier
Ontario Dept. of Agriculture
Queens Park
Toronto, Ontario, Canada

Mr. R. H. Redmer
13312 Arctic Ave.
Rockville, Md. 20853

Mr. G. Reed
Universal Foods Corp.
433 E. Michigan St.
Milwaukee, Wis. 53201

Mr. G. Rey
Industrial Pollution Control R & D
1921 Jefferson Davis Highway
Arlington, Va. 22202

Mr. A. Richardson
519 Pleasant St.
Belmont, Mass. 02178

Mr. Alan Riedinger
San Diego, Calif.

Mr. N. E. Roberts
Information Division
Agricultural Research Service, USDA
Philadelphia, Pa. 19118

Mr. W. T. Robinson
Organic Chemicals Dept.
E. I. DuPont, "PERMASEP" Prod.
Wilmington, Del. 19898

Mr. K. W. Royer
Box 27
Mayville, Wis. 53050

Mr. A. M. Sadler
Eastern Utiliz. Res. and Dev. Div.
Agricultural Research Service, USDA
Beltsville, Md. 20705

Mr. T. H. Sappie, Jr.
1234 Riedsdale St.
Pittsburgh, Pa. 15233

Mr. A. Sargant
75 Bathurst St.
London, Ontario, Canada

Mrs. Nancy Savage
Brandt Chemical
Portland, Oreg.

Mr. M. Schamback
4900 Maspeth Ave.
Queens, N. Y. 11378

Mr. J. Scheder
Box 27
Mayville, Wis. 53050

Mr. W. W. Schmentas
R. 1
Granton, Wis. 54736

Mr. E. F. Schoppet
Eastern Utiliz. Res. and Dev. Div.
Agricultural Research Service, USDA
Philadelphia, Pa. 19118

Dr. F. R. Senti
Office of Administrator
Agricultural Research Service, USDA
Washington, D. C. 20250

Mr. R. Q. Seward
RFD The Seward Family Inc.
East Wallingford, Vt. 05742

Mr. M. W. Sills
Economic Research Service, USDA
Philadelphia, Pa. 19118

Mr. M. T. Silverman
170 Saw Mill River Road
Yonkers, N. Y. 10701

Mr. Thom Simmons
C. E. Rogers Company
8731 Witt St.
Detroit, Mich. 48209

Mr. H. I. Sinnamon
Eastern Utiliz. Res. and Dev. Div.
Agricultural Research Service, USDA
Philadelphia, Pa. 19118

Dr. Janusz S. Skupin
Poznan, Poland

Mr. S. L. Smith
145 E. Genesee St.
Auburn, N. Y. 13021

Mrs. Ellen Spear
1526 S. State St.
Chicago, Ill. 60605

Mr. D. Storhoff
Associated Milk Producers, Inc.
Clarkfield, Minn. 56223

Mr. R. Streeter
Ferryville Cheese Co., Inc.
Uragua, Wis. 54628

Mr. J. P. Tailor
Tailor and Company
P. O. Box 587
Davenport, Iowa 52805

Mr. W. C. Thacker
3939 W. Market
Drawer M-2
Greensboro, N. C. 27402

Mr. F. Thomas
Haven Dairy Corp.
Hogan, S. D.

Mr. P. B. Thompson
Food and Drug Administration, USDA
Washington, D. C. 20250

Mr. J. Thurston
3807 S. Park Ave.
Blasdell, N. Y. 14219

Dr. R. S. Timmina
341 Vassar St.
Cambridge, Mass. 02139

Dr. R. Townend
Eastern Utiliz. Res. and Dev. Div.
Agricultural Research Service, USDA
Philadelphia, Pa. 19118

Dr. R. H. Treadway
Eastern Utiliz. Res. and Dev. Div.
Agricultural Research Service, USDA
Philadelphia, Pa. 19118

Dr. H. C. Trelogan
Statistical Reporting Service
U. S. Department of Agriculture
Washington, D. C. 20250

Mr. L. C. True
Drawer DD
Mississippi State University
State College, Miss. 39762

Mr. O. D. Turner
925 E. Maple Rd.
Birmingham, Mich. 48011

Dr. D. Vaughan
Human Nutrition Research Division
Agricultural Research Service, USDA
Beltsville, Md. 20705

Mr. D. Vell
1212 State Ave.
Cincinnati, Ohio 45204

Mr. H. H. Wagner
Gaile Corp.
Weyauwega, Wis. 54983

Mr. J. T. Walsh
130 N. Franklin St.
Chicago, Ill. 60606

Mr. H. E. Walter
Eastern Utiliz. Res. and Dev. Div.
Agricultural Research Service, USDA
Beltsville, Md. 20705

Mr. P. E. Walter
Route 4, Box 22G
Oklahoma City, Okla. 73111

Mr. K. W. Ward
111 Pine St.
San Francisco, Calif. 94111

Mr. G. H. Watrous, Jr.
647 Fairway Rd.
State College, Pa. 16801

Mr. K. S. Watson
Kraftco Corp.
Research and Development Division
801 Waukegan Rd.
Glenview, Ill. 60025

Dr. B. H. Webb
Eastern Utiliz. Res. and Dev. Div.
Agricultural Research Service
Washington, D. C. 20250

Mr. R. Webber
2723 Bowling Green Drive
Vienna, Va. 22180

Dr. M. I. Wegner
Federal Center Bldg., Rm. 327
U. S. Department of Agriculture
Hyattsville, Md. 20782

Dr. S. M. Weisberg
League for International Food Education
1155 Sixteenth St., N.W.
Washington, D. C. 20036

Mr. C. C. Whitcome
DeLaval Supply Co.
Poughkeepsie, N. Y. 12602

Mr. R. G. White
2404 Pennsylvania Ave.
Evansville, Ind. 47721

Mr. C. W. Wiekey
Northland Foods
Shawano, Wis. 54166

Mr. R. A. Williams
General Foods Corp. Technical Center
555 S. Broadway
Tarrytown, N. Y. 10591

Dr. R. L. Winslow
2538 Telegraph Ave.
Oakland, Calif. 94612

Dr. I. A. Wolff
Eastern Utiliz. Res. and Dev. Div.
Agricultural Research Service, USDA
Philadelphia, Pa. 19118

Miss Madelyn Womack
Human Nutrition Research Division
Agricultural Research Service, USDA
Beltsville, Md. 20705

Mr. N. P. Wong
Eastern Utiliz. Res. and Dev. Div.
Agricultural Research Service, USDA
Washington, D. C. 20250

Mr. A. C. Woodruff
324 Spring Valley Rd.
Springfield, Pa. 19064

Mr. P. K. Worsley
Ajax International Corp.
819 Reddick St. - P. O. Box 4007
Santa Barbara, Calif. 93103

Dr. J. H. Woychik
Eastern Utiliz. Res. and Dev. Div.
Agricultural Research Service, USDA
Philadelphia, Pa. 19118

Mr. H. Young
500 N. Peshtigo Court
Chicago, Ill. 60690

Dr. R. Zall
145 Conklin Ave.
Binghamton, N. Y. 13093

Appendix 2

SOME COMMERCIAL FOOD AND FEED PRODUCTS MADE FROM OR CONTAINING WHEY

The Whey Utilization Conference featured displays of commercial products made from or containing whey. In an effort to make these proceedings as complete as possible, the following listing of such products is offered. This is only a partial listing from some of the major producers, and the products are cited only as examples. There is no intention to imply endorsement of the products listed by the U. S. Department of Agriculture over others not mentioned. By indicating some of the commercial products into which whey is now going, the listing is provided as a stimulus to thinking about further potential uses.

Whey-Containing Food Products

Manufacturer	Product
Adams Corp.	Chip Dip (Smoky Cheddar cheese, toasted onion, bacon horseradish)
Continental Baking Company, Inc.	Macaroni and cheese casseroles Macaroni and cheese dinners Coconut custard pie Fruit creme pies (all varieties) Cream pies (all varieties) Pumpkin pie Danish (all varieties) Donuts Corn and blueberry muffins German chocolate cake Dinners (all varieties with mashed potatoes) Profile bread Wonder cheese twists
Deran Confectionery Co., Inc.	Licorice toffee
Fisher Cheese Company	Chefs' Delight (cheese)
R. T. French Company	French's Cheese Sauce Mix French's Sour Cream Sauce Mix French's Cheese Potato Bakers
General Foods Corp.	Jello Chocolate Cream Pie Dream Whip Jello Golden Egg Custard D-Zerta Whipped Topping (low calorie)
Gerber Cheese Company, Inc.	Wispride (cheese dip)
Green Giant Co.	Frozen vegetable sauces

Green Giant Co. (continued)	Vegetable casseroles
	Fixed 'n Fancy vegetable line (such as cauliflower frozen in cheese sauce)
Keebler Company	Club Crackers
	Wheat Toast
	Vanilla Wafers
	Cinnamon Crisp
	Spiced Windmill Cookies
	Cocoanut Bar Cookies
	Onion Toast
	Butter Flavored Thins
	Keebies
Kellogg Company	Pop-Tarts
Kraft Foods	Caramels
	Fudgies
	Grated American Cheese Food
	Process cheeses
McCormick and Company, Inc.	Sour Cream Sauce Mix
Morton Frozen Foods (Continental Baking Company)	Lime Cream Pie
National Biscuit Company	Snack Mate Cheese Spread
	Chippers Potato Crackers
	Chit Chat Crackers
	Bacon Flavored Thins (crackers)
	Pride (assortment of cookies)
	Vanilla Wafers
	Chocolate Chip Cookies
	Snack Mate Process Cheese Spreads
	Crown Peanut Bars
	Barnum's Animal Crackers
	Cheese on Rye Sandwich
	Lorna Doone Shortbread
	Marshmallow Puffs
	Social Tea Biscuits
Nestle Company	Sugar Cookie Mix
	Toll House Cookie Mix
	Chocolate Mint Cookie Mix
	Lemon Cookie Mix
Ovaltine Food Products	Ovaltine
Pillsbury Company	Hungry Jack Biscuits
	Hot Roll Mix
Quaker Oats Co.	Aunt Jemima Complete Pancake Mix

Quaker Oats Co. (continued)	Cap'n Crunch Crunch Berries Burry Cookies: Mr. Chips Coconut Chocolate Chips Fudgetown Homestyle Oatmeal Cookie Toasted Coconut Cookie Burry's Best Oatmeal Cookie Burry's Best Pecan Cookie Ginger Mint Cookie Fudge Shortcake - vending Girl Scout Thin Mints Sierra Eclairs Shortbread Cookie Euphrates Wheat Wafer Smokey Joes (contain partially delactosed whey solids) Chiks (contain partially delactosed whey solids)
Rite Bite Food Products	Cracker and Cheese (snack pak 10 in 1)
Sunshine Biscuits, Inc.	Cherry Coolers (cookies) Mint Hydrox Cookies
Tootsie Roll Industries, Inc.	Tootsie Rolls
William Underwood Co.	B & M Brown Bread

Whey Products Used as Ingredients in Food Manufacture

Manufacturer	Product	Description
Amber Laboratories	Amberskim	--
Bongarde Creameries	Bon-O-Lac blends	Whey blends for bakery and dairy products. Also custom whey blends.
Foremost Foods	Whey-Cysteine	For soda crackers
	Nutrimix 500	Whey-skim milk blend for ice cream
	Redi-Sponge	Whey + L-cysteine for baking
	Kwik-Dough	Whey + L-cysteine to replace sponge step

Manufacturer	Product	Description
Foremost Foods (continued)	Whey-Cystein, M28	To eliminate brew in baking
	Nutritek 250	Demineralized whey for ice cream
Kraft Foods	Kraflow	Whey + gelatin. Flow agent for high-fat products
	Dairy Blend 100	1/2 Whey-1/2 skim milk for many uses
	Krafen	Sweet whey for all food uses
	Kralex	Whey + protein and minerals for baking
	Mel-O-Ward	Treated whey for baking
	Ferm-O-Lac	Whey + buttermilk for baking
	Flavor Guard	Whey + skim milk for baking
John Kraft Sesame Corp.	Sesa-Lac	Sesame and whey
Land O'Lakes		Sweet dairy whey and custom whey blends
Maple Island, Inc.		Bakery, dairy, and other custom whey blends
Nestle Co., Food Ingredients Division	Product Type K	Dehydrated cheddar cheese
	Product Type F	Dehydrated cheese
Paniplus Company	Extram-Blue Label	Whey mix for baking
	Panilac	Whey mix for baking
Precision Foods Corp.	Merilac	Whey mix
Purity Foods, Inc.	LP 10, LP 20	Demineralized whey
Swift Chemical Co.	Provide	Dried whey-soy mixture for bakery products, candy, frozen desserts

Whey-Containing Animal Feed Products

Manufacturer	Name
Foremost Foods	M-N-C (Milk-Nutrients-Concentrated), a feed and pellet binder
	Whey products for mixed feeds
	Soweena, milk replacer for baby pigs
Kraft Foods	Kaff-A Milk Replacer, Medicated
	Kaff-A Booster Pellets and Crumbles
	Pig Pre-Starter, Medicated
	Nutri-Plus Pellets and Crumbles for Sheep
	Pex Feed Booster Pellets and Crumbles for Poultry
	Pace Feed Booster Pellets and Crumbles for Horses
Milk Specialties, Inc.	Dari-Dri Baby Calf Formula
	Dari-Dri Baby Pig Weaner
	MS Custom Milk/Fat Mixes
	Midwest Sweet Dried Whey
Quaker Oats Company	Puss'n Boots Kidney and Gravy
	Puss'n Boots Liver and Gravy
	Puss'n Boots Horsemeat and Gravy
	Puss'n Boots Gourmet Feast
	Ken-L Ration Mighty Morsels

☆U.S. GOVERNMENT PRINTING OFFICE: 1971-705-032/251

UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
EASTERN MARKETING AND NUTRITION RESEARCH DIVISION
600 EAST MERMAID LANE
PHILADELPHIA, PENNSYLVANIA 19118

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